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Chemical Engineering

JUNE 1956

compression

64 PAGE REPORT.

- WHERE COMPRESSORS ARE USED TODAY
- HOW TO SELECT FOR PROCESS NEEDS
- WHERE THEY FIT, HOW THEY OPERATE

PILOT PLANT DESIGN:
Philosophy or formula? . . p. 239

THE NEW GRADUATES:
Smarter than ever . . . p. 268

JUNE 1956

JOHN R. CALLAHAM, Editor

Keeping Tabs

Our biggest job is to keep in touch with you and to give you (if possible) what you want. And unless we do right well, we lose subscribers fast (we're now gaining them fast).

Most important is our personal contacts through travel, correspondence, meetings, luncheons. CE's emphasis on readers' needs makes it logical that close to 85% of our contacts are with technical men, largely engineers.

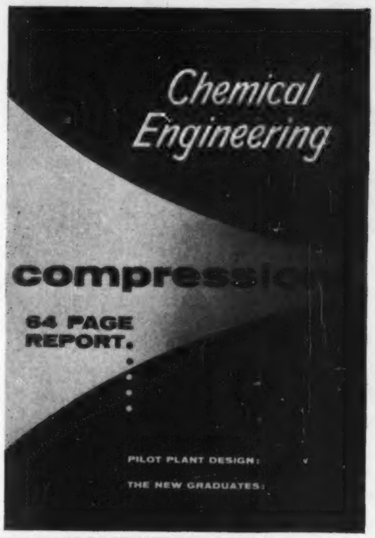
Each year we chalk up 80,000-95,000 miles of out-of-town travel. Most of this is for trips to processing plants, engineering offices, development laboratories. Within the past five years we have visited (at least once) 90% of the major chemical plants in the U. S.

Several times a year trained interviewers make a field study of the readership of one particular issue of CE. These surveys, based on a sample of about 200 subscribers, are conducted by professional researchers. CE has been the only chemical publication to use this advanced—and expensive—research tool on a continuing basis since 1948.

For almost 7 years CE editors have sent out a mail questionnaire each month to a rotating, cross-section list of 1,000 subscribers. Each of our 40,000 subscribers thus has a chance to "vote" his editorial likes and dislikes about every three years.

We also use other indicators: Reader Service inquiries (of which we receive upwards of 15,000 each month); unsolicited letters (hundreds a month); reprint sales (to pinpoint most popular subjects); magazine preference studies (how we stack up with others in the field); reasons for non-renewals (why CE isn't worth $3 a year to some people).

We hope you use every opportunity to tell us your reactions. They help keep us on our editorial toes!



GUIDED TOUR

How to tackle your compressor problems with today's know-how

Packed into this month's 64-page report you'll find up-to-date advice and expert help on an operation that's almost universal. Ten authors give you the reasons for compression, the bases for ultimate choice, principles and characteristics of the six main compressor types. (p. 175)

For process control: A brand new tool

There's considerable excitement about the new technique called gas-liquid partition chromatography. Both versatile and practical, it promises real savings in automatic process control. (p. 116)

Modern approach to pilot plant design

How, where and why to build. This philosophy of pilot plant design reviews

Please turn page

Chemical Engineering

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GUIDED TOUR

the problems for you. It'll guide you past the pitfalls of scale-up. It'll help you confound the so-and-so who says the pilot plant is the place to make errors. (p. 239)

More help in picking the right alloys

Now a general classification scheme gives you the basis for intelligent choice of hard-surfacing alloys to lengthen the surface life and service life of your valuable process equipment. (p. 243)

Winnowing your share of the new crop

How to get the recent graduate off to the right start in his new job with your company. What his academic background is and what you should do to fit it into your operations successfully. (p. 268)

Ammonia flouts tradition

Coke-oven gas as a source of hydrogen for ammonia? Here's the why and how of the advancing low-temperature technology that's made possible the first U. S. plant designed for this raw material. (p. 400)

Rejoin GUIDED TOUR page 316

CHEMICAL ENGINEERING

June, 1956 Vol. 63—No. 6

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To keep pace with the chemical, petrochemical and chemical process industries, more engineers subscribe to Chemical Engineering than to any other publication. Total net paid circulation of this issue:

40,455

How four tough, diverse chemical packaging jobs were solved with Bemis Bags . . .

caustic materials

problem: **Develop a shipping container with special properties to resist the corrosive action of the contents . . . and to cost less than the rigid containers previously used.**

solution: **A special multiwall paper bag, made by Bemis . . . a sewn valve type with a polyethylene-coated inner sheet . . . that cost only about one-third as much per hundredweight (including filling and closing labor) as the containers previously used. Further savings were made in storage space of both empty and filled containers and in lower shipping costs due to reduced tare weight.**

---

powdered aluminum

problem: **The product must be protected against moisture and the shipping container must also be tough enough to stand up in export shipment.**

solution: **Bemis Waterproof (laminated-textile) Bags, which gave the necessary moisture protection and the required durability (they're the toughest shipping bags made). Furthermore, they save the shipper a lot of money, as the bags cost about 40 cents each, as compared with $1.25 for drums of equal capacity. There is also a substantial saving in empty container storage space.**

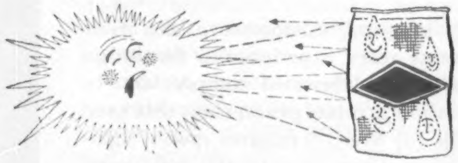
polystyrene crystals

problem: **Develop a shipping container that will (a) keep the polystyrene crystals entirely free from foreign matter, even down to lint particles, (b) withstand the rigors of export shipment, involving multiple handling, exposure, etc., and (c) cost less than the double-packaging (with overslips) previously used.**

solution: **A special type of laminated-textile valve bag developed by Bemis. The bag is constructed of tough burlap laminated between two types of special paper . . . providing ample strength, resistance to abrasion and freedom from lint. An ingenious method of sewing prevents burlap lint from getting into the polystyrene. Substantial savings are made on every bag shipped, not only on bag cost but also on labor.**

resin beads

problem: **Find a lower cost, easier handling shipping container for ion exchange resin beads in which the moisture content must be maintained at its original approximate 45%. The material was previously shipped in fiber drums.**



solution: **A Bemis Waterproof (laminated textile) Bag, with a loose poly liner. After being filled, the liner is tie-closed and the burlap bag is closed by sewing. Advantages — Necessary moisture content is retained. Shipping weight is substantially reduced. Bags are more easily handled and require less unloading time. Drum disposal problem is eliminated. There is a storage space saving of 30% on filled bags and an even greater saving in empty container storage space.**

Whether your shipping container problems are similar to any of these . . . or far removed from them . . . it's likely that Bemis can help you reach a money-saving solution. Write, wire or phone us. You will soon know whether we can help you.

Bemis

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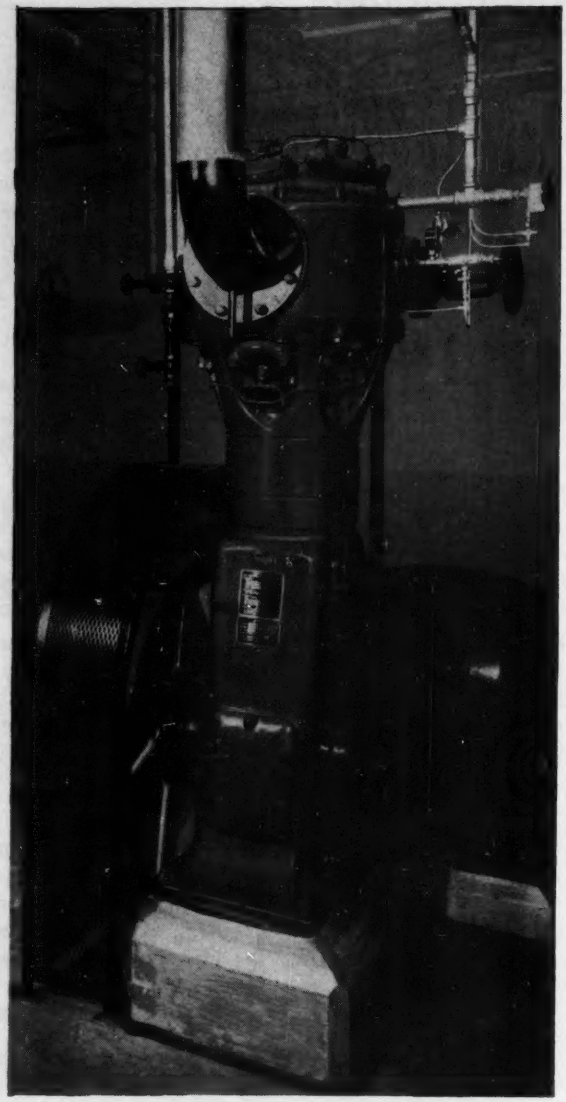
OIL-FREE AIR?

You'll be three steps ahead with the JOY WGO-9 COMPRESSOR



1 **VERTICAL DESIGN**—Saves floor space, allows simple installation. Prevents uneven wear in carbon rings. Eliminates necessity for periodic turning of piston to equalize ring wear.

2 **LONG-ROD CONSTRUCTION**—Spacer between crankcase and cylinder absolutely prevents passage of oil into cylinder. No part of the piston rod that enters the crankcase can enter the cylinder. No possibility of air contamination.

3 **SECTIONALIZED CARBON RINGS**—Expanders maintain ring-contact with cylinder wall despite wear. Rings last longer.

The Joy WGO-9 "long-rod" compressor is the result of more than twenty years' experience in the design and manufacture of non-lubricated compressors. In addition to the carbon graphite piston rings that need no lubrication, the Joy WGO-9 features special lightweight pistons; large, direct air passages; and liberal waterjacketing to reduce heat and minimize ring wear.

The patented Dual-Cushion Valves are made of corrosion-resistant materials. In addition, all metallic wearing surfaces are either chrome-plated, surface-hardened, or made of stainless steel.

Free Bulletin gives details on the Joy WGO-9 Oil-Free Compressor. Write for your copy TODAY to ***Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pa.*** In Canada: *Joy Manufacturing Company (Canada) Limited, Galt, Ontario.*

Write for FREE Bulletin 57-11

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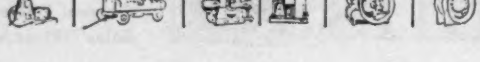
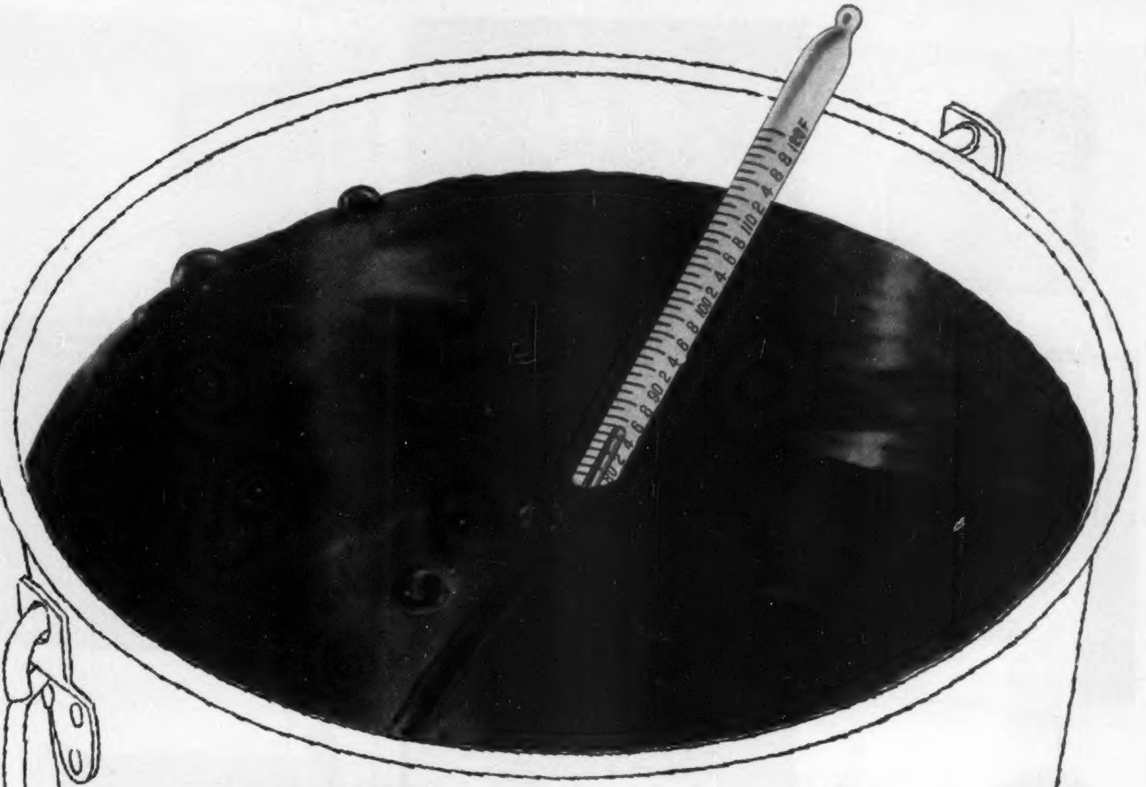


W&W 15589-57

JOY

SPECIALISTS IN THE COMPRESSION AND MOVEMENT OF AIR AND GASES SINCE 1885

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Seamless fittings with all the plus values...at no extra cost
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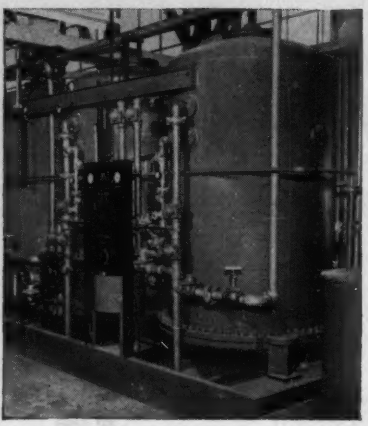
News about

B.F.Goodrich Chemical *raw materials*



Easy-to-install Geon rigid vinyl pipe lasts longer

THE exceptional physical and chemical properties of pipe and fittings made from Geon rigid vinyl resins have cut costs in many systems and made entirely new applications possible. Here are the reasons:

1. **Resists oil, acids, alkalis, most chemicals.**
2. **Has high tensile and impact strength.**
3. **Resists sunlight, fungi, bacteria, moisture, heat and cold.**
4. **Smooth internal surface reduces flow resistance.**
5. **Rigid enough for overhead installation with pipe supports, but flexible enough to absorb shocks.**
6. **Easy to install. Lightweight (see photo), fittings attached by solvent cementing, threading, heat welding or adhesives.**
7. **Being a non-conductor, does not support electrolytic action.**

Applications include sour crude oil lines, salt water lines, chemical plant piping, industrial cold water lines, vent pipes for acid fumes and corrosive gases. Vinegar plants, ships at sea, oil fields—all are enjoying the rewards of cheaper and easier installation, lower material cost and longer pipe life under extreme conditions.

Send for new bulletin on Geon 8700-A—describes properties, applications, advantages of rigid unplasticized polyvinyl chloride compounds. Write Dept. DB-6, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

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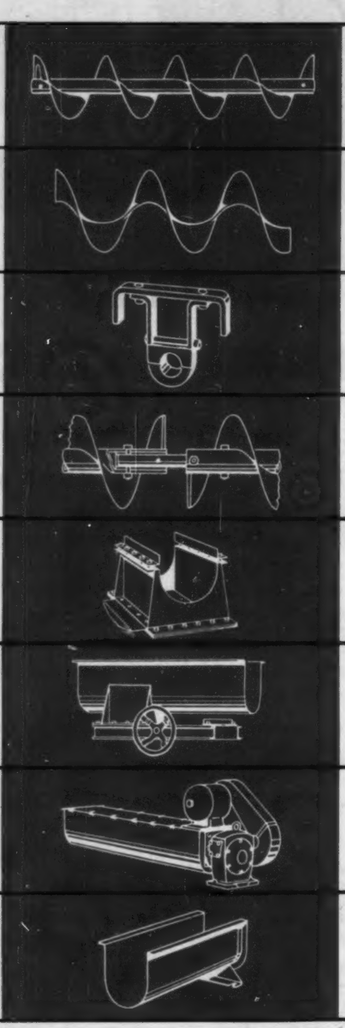
When you buy screw conveyors... rate them against this quality chart

Only LINK-BELT gives you all these performance extras



ACCURATELY FORMED FLIGHTING	Link-Belt's specialized machinery assures accurate forming, producing uniformity of flighting curvature.
UNIFORM DIAMETERS	Only specially selected steels are used to meet Link-Belt's rigid specifications.
WIDE RANGE OF HANGERS	Hangers are available in a wide range of styles and mountings with various bearing materials.
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ON-THE-JOB DISCHARGE OPENING LOCATION	For versatility in locating discharge openings, Link-Belt offers spouts and gates that can be easily installed on the job and bolted or welded in place.
CHOICE OF SPOUTS, GATES	Wide range of fixed or detachable plain discharge spouts or gates. Flat or curved slide type gates can be hand or rack-and-pinion operated.
FULLY INTEGRATED DRIVES	Only Link-Belt builds a complete, pre-integrated line of gear and chain drives, couplings, bearings. One proved source . . . one undivided responsibility.
ACCURATELY FABRICATED TROUGHS	Added refinements of manufacture assure better fit of all components. And Link-Belt offers you a choice of metals to fit your particular application.

These are only a few of the many important performance extras you get with Link-Belt screw conveyors. Ask your Link-Belt representative or authorized stock carrying distributor for 92-page Data Book 2289.

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13,877

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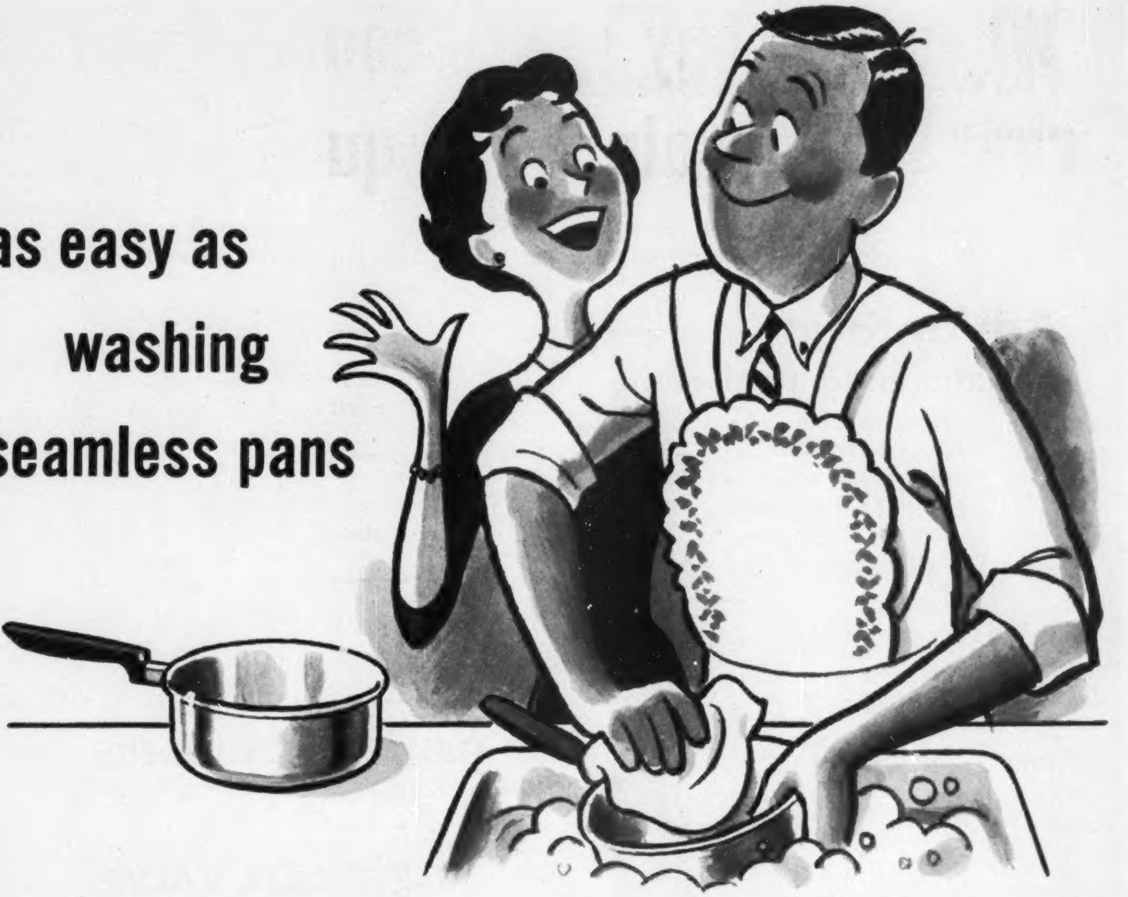
as easy as washing seamless pans



Seamless chimes of Hackney two-piece acid drums harbor no acid traces between shipments

Here's one reason why so many leading sulphuric acid producers ship in Hackney Acid Drums.

Hackney two-piece acid drums are made with entirely *seamless chimes.* They have no interior cracks or crevices where acid traces can linger and carry on intensive corrosion between shipments. Controlled heat treatment further increases corrosion resistance of selected, top-quality steel.

Meet ICC specifications for the safe transportation of corrosive liquids such as sulphuric acid, aqua ammonia, titanium tetrachloride, caustic potash and many others.

Standard capacities of 15, 20, 30, 55 or 110 gallons. Send today for Drum and Barrel Catalog and minimum quantity data.

Rugged and Durable—Take shipping and handling abuses on the chin, thanks to such construction features as reinforced chimes, sturdy I-bar rolling hoops, heavy forged spuds.

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Here is Why!

You can dispense with oil filters and dust filters when you install ®Nash® Clean Air Compressors. You can save the cost of maintaining these devices. You can greatly reduce instrument maintenance costs. For the Nash employs no internal lubrication, therefore no troublesome oil is in the delivered air. Moreover, air from a Nash is thoroughly washed and cooled as it passes thru the pump. Dust in the plant atmosphere, even fly ash, is immediately removed.

®Nash® Clean Air Compressors are simple, with only one moving element. No valves, gears, pistons, sliding vanes, or other enemies of long life and constant performance complicate a Nash. No aftercoolers are needed. You will find it profitable to investigate these pumps, now.

- No oil filters.
- No dust filters.
- No internal lubrication to contaminate air handled.
- No internal wearing parts.
- No valves, pistons, or vanes.
- Non-pulsating pressure.
- Original performance constant over a long pump life.
- Low maintenance cost.

NASH ENGINEERING COMPANY
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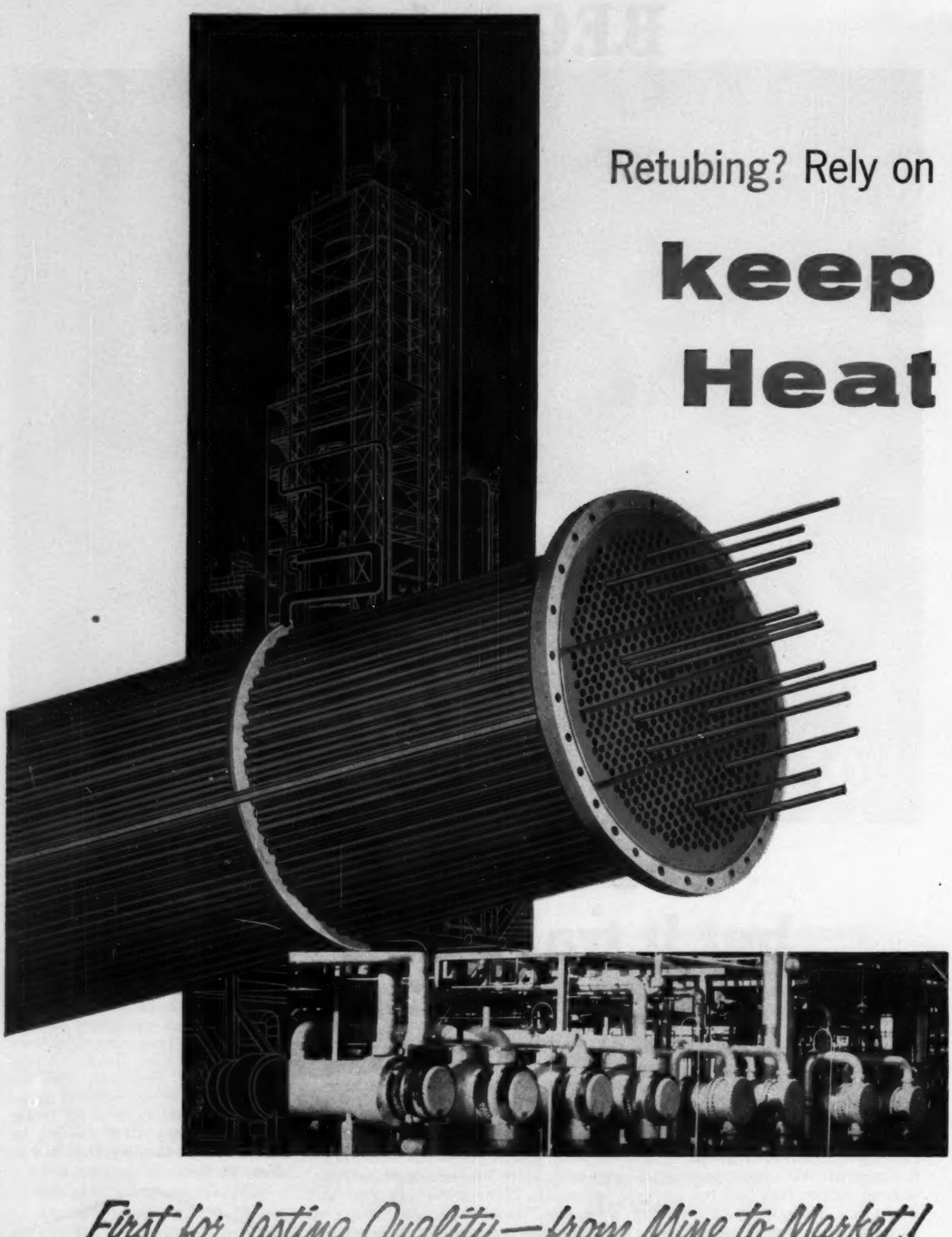
Retubing? Rely on

keep Heat



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Phelps Dodge COPPER-BASE ALLOY Tubes to

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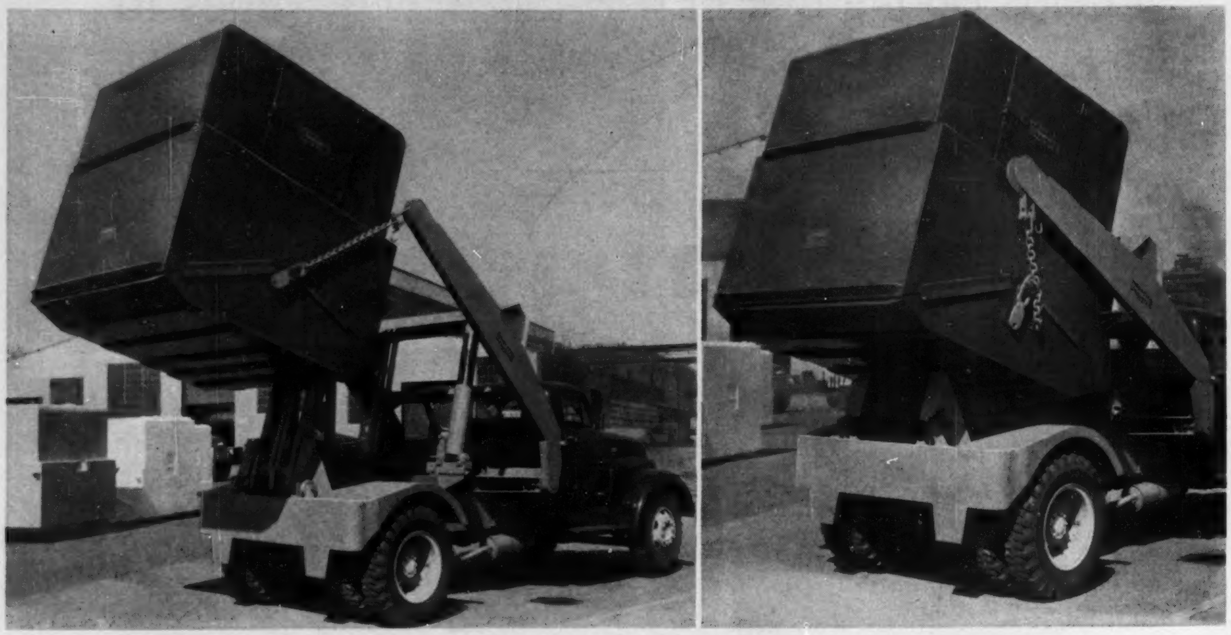
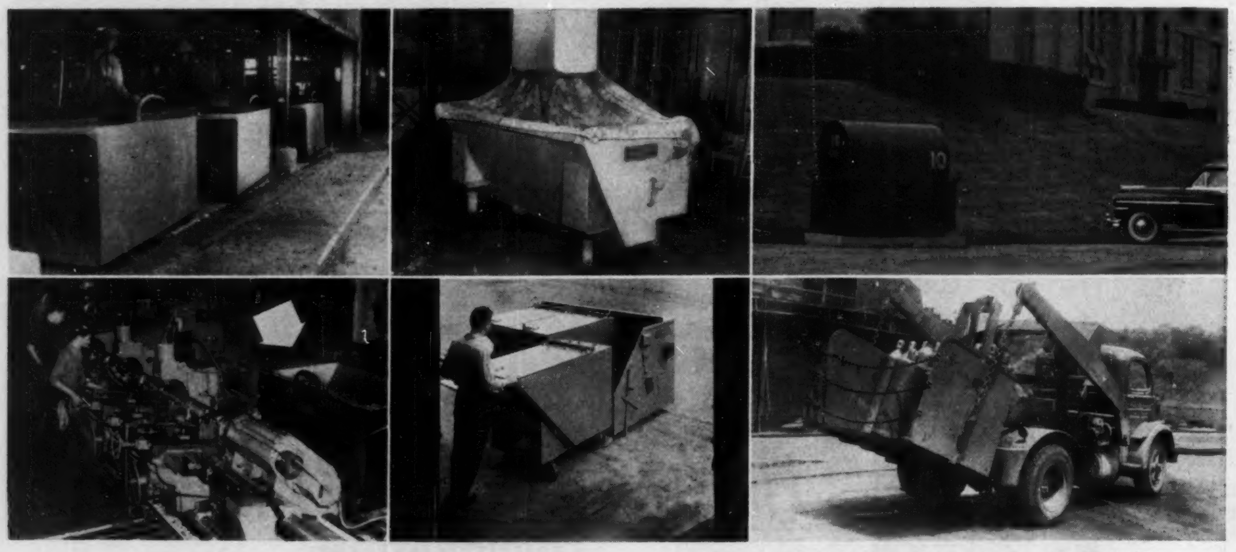
Here's the most versatile....lowest cost of bulk materials handling by truck ever



With only one man, it PICKS UP . . . HAULS . . . Serves scores of big steel containers, all sizes and

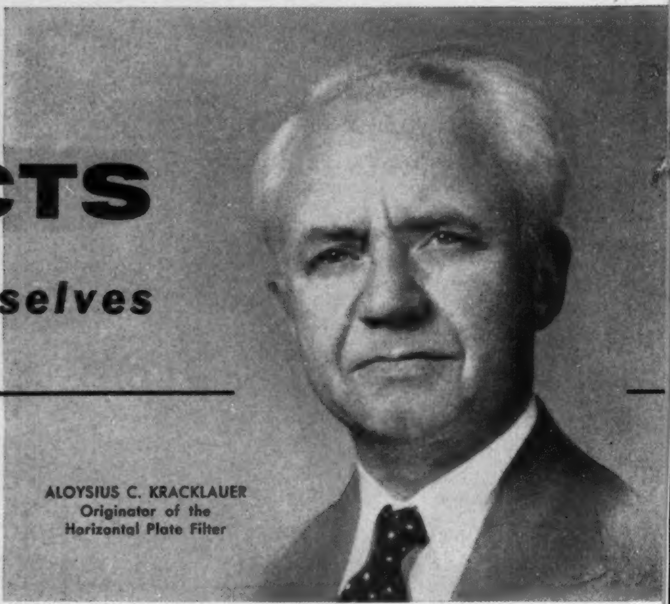


It's the DEMPSTER DUMPSTER® System

ABOVE ARE BUT A FEW of the hundreds of different Dempster-Dumpster Detachable Containers at work in industry today—containers built in capacities up to 21 cu. yds. . . . several times the capacity of the average dump truck body. It's like having one truck with scores of bodies!

FILTER FACTS

. . . that speak for themselves

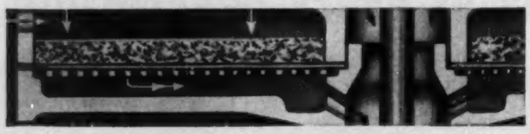


ALOYSIUS C. KRACKLAUER
Originator of the
Horizontal Plate Filter

The Sparkler original, exclusive horizontal plate design and flow principle has never been equaled for efficiency in filtering with various filter aids such as diatomite, activated carbon, activated clay, asbestos fibre, cellulose fibre, fuller's earth, etc.

1. HIGH FLOW RATE OBTAINED

Substantially higher flow rates and longer cycles are obtained with Sparkler Horizontal Plates than with filter septa in a vertical plane. Rather than being impacted into position, the filter aid is floated into position naturally and gently, making for a more uniform, interlaced, and more porous filter cake. It also enables the precoating and initial cycling to be done at lower velocity, which again results in a more sponge-like cake that permits freer flow, and ultimate longer cycle.



One glance at the cross section of a Sparkler horizontal plate and it is easy to see how such high flow is a natural result of this position of the cake. This illustration of the cross section of a plate shows the cake resting on the filter paper supported by the screen and the ample drainage space below the plate.

2. CAKE STABILITY ASSURED

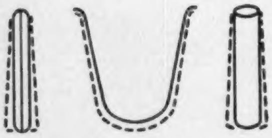
When a cake is built up on a horizontal plate it rests secure without strain and maintains its original position as formed regardless of pressure fluctuation, flow rate or viscosity. Even a complete shut down of the filter will not disturb the cake. The filter can be moved about and filtering resumed at any time with complete confidence that the cake has not cracked or slipped. Only on a horizontal type of plate can this positive cake stability be maintained.

SPARKLER horizontal plate FILTERS

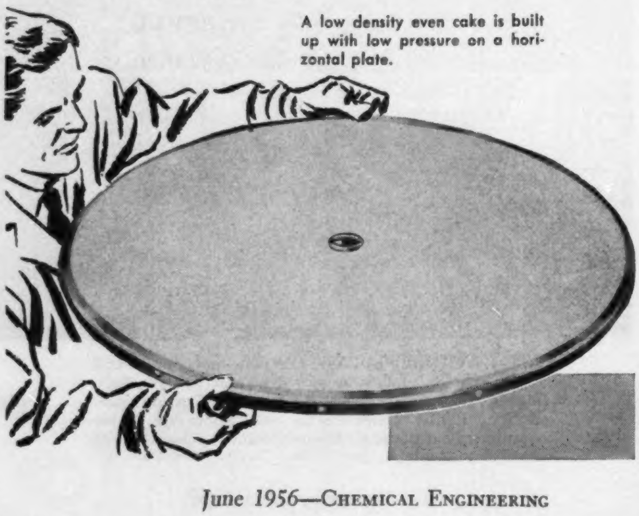
3. PRECOAT ECONOMY

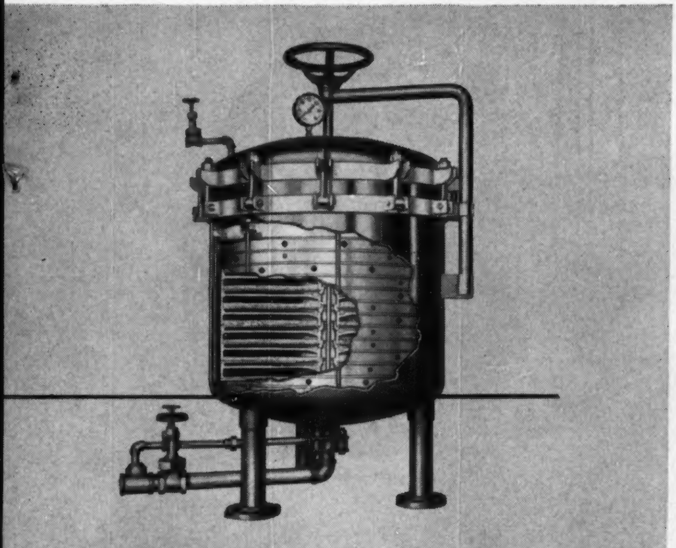
It may be surprising to find how much time and filter aid can be saved in precoating horizontal plates. The use of fibrous materials (such as asbestos) to obtain cake cohesion can be completely eliminated. Floating the filter aids into position, assisted by gravity, makes for a uniform thickness of cake across the entire face of the plate, hence a thinner precoat will suffice. Add to these advantages the possibility of using a relatively dense filter paper on a Sparkler horizontal plate and you have reduced the cost and time of precoating to a very minimum.

On a vertical plate, bag, or tube, pressure is required to pre-coat, and to hold the cake during the filtering cycle. There is a tendency for the pre-coat and cake to build up thicker at the bottom with an uneven resistance to the passing of liquids. Frequently a fibrous pre-coat is required to obtain cohesion for holding the cake.



A low density even cake is built up with low pressure on a horizontal plate.



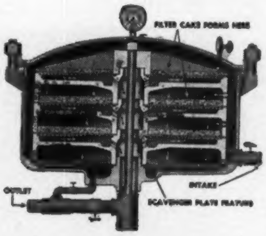


Standard horizontal plate filter construction.

4. CAKE WASHING AND DRYING

Since the cake is uniform on every plate all the way across, no channeling or by-passing is encountered in washing. Tests have shown that with a volume of wash liquid equivalent to the volume of the filter, the cake can be washed to a content of less than 1/10 of 1% of dissolved material.

Cake drying by blow-down reduces the amount of liquid held in the cake well below 15%. This compares with other types of filters where the retention may run as high as 35%. The patented scavenger plate in Sparkler Horizontal Plate Filters permits recovery of the liquid left in the filter down to almost the last drop.



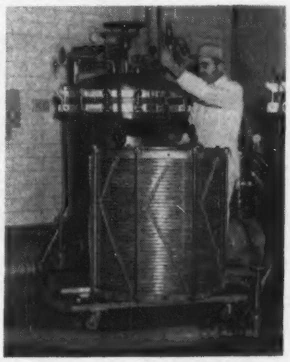
Note, patented scavenger plate at bottom of the filter tank provides for recovery of practically the "last drop."

5. FREE DRAINAGE OF EFFLUENT

In the Sparkler plate design a special effort was made to reduce the flow friction of the filtrate to a very minimum. To do this, a rigid perforated metal screen is used to support the filter septum, and these perforated screen plates in turn are supported by uniformly spaced heavy raised dimples in the filter plate. This arrangement gives an unobstructed flow of the filtrate to the outlet port. A very important feature for large unit volume and for handling relatively high viscosity liquids.

6. QUICK CHANGE CARTRIDGE

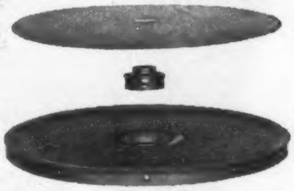
The Sparkler horizontal plates are assembled, bolted together, in a cartridge unit which can be removed and a clean dressed set of plates inserted in the filter in a matter of minutes. Thus the down time for cleaning is reduced to a negligible factor compared with filters that require a disassembly job for cleaning. A continuous flow filtration can be maintained when a battery of two or more Sparkler Horizontal Plate Filters are used as a unit due to the quick plate change feature.



A spare set of plates can be cleaned and dressed without shutting down the filter.

All Sparkler filters are completely enclosed to avoid risk of explosion in filtering volatile or flammable liquids. Filters can be jacketed at low cost for brine or gas-liquid refrigeration or for steam or high temperature heating liquids.

All stainless steel filters are available, and with the access to all surfaces of the plate for thorough cleaning, a completely sanitary filter is thus provided for food products.



Sparkler horizontal plates are easily dismantled for cleaning every inner surface making possible complete sanitation.

Other structural metals include nickel, mild steel, Hastelloy, monel and bronze.

Sparkler Horizontal Plate Filters are widely used for chemicals, foods, pharmaceuticals, beverages, beer, whisky, oils, petroleum derivatives, plating solutions, and many other products. Available in capacities up to 200 sq. ft. of filtering surface. Multiple units recommended for larger requirements. All sizes can be portable.

Write Eric Anderson—our filtration engineering service is available to help solve your filtration problems.

SPARKLER MANUFACTURING CO.

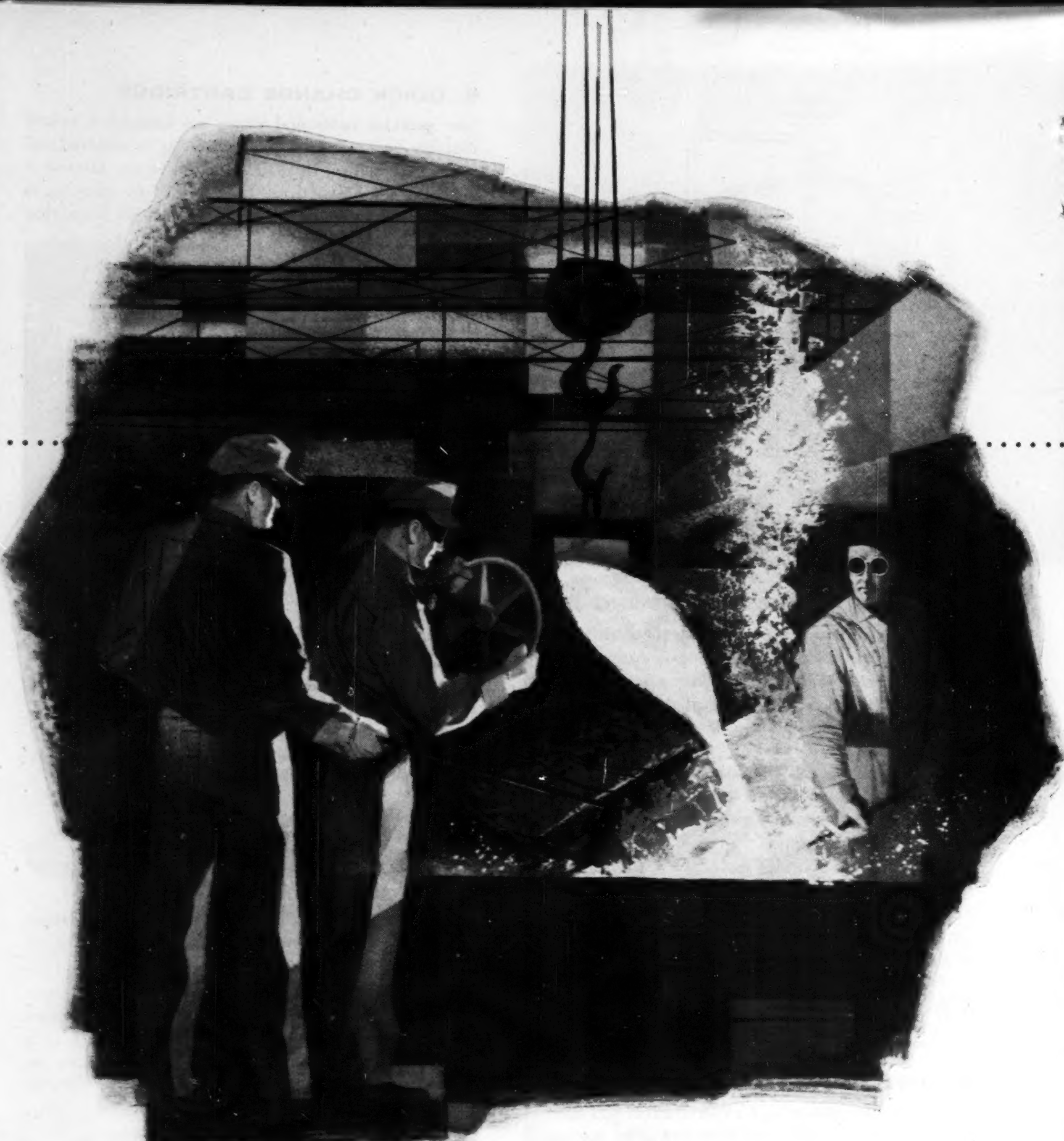
MUNDELEIN, ILLINOIS

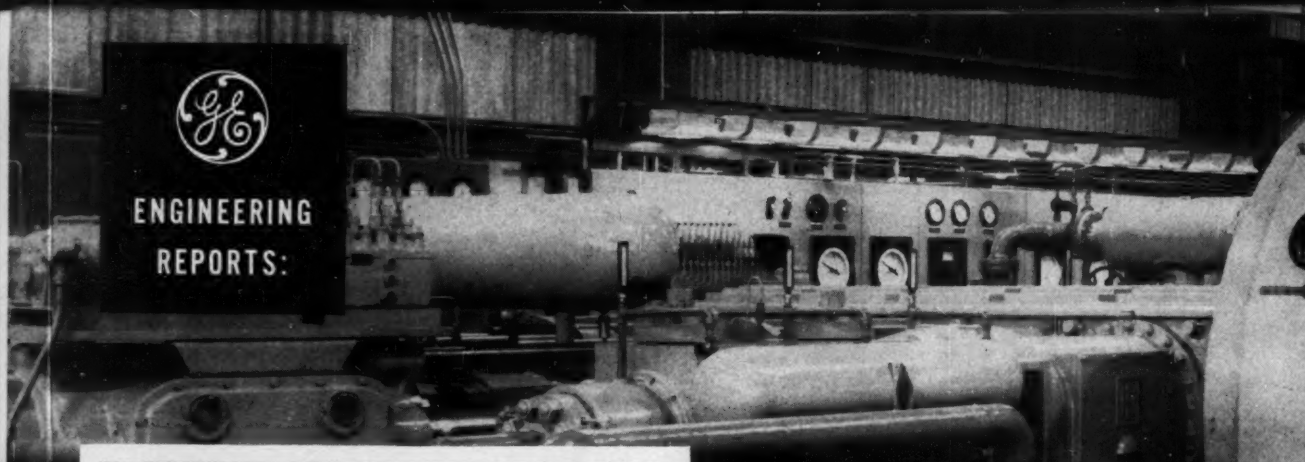
Sparkler International Ltd., Manufacturing plants in Canada, Holland, Italy, and Australia.

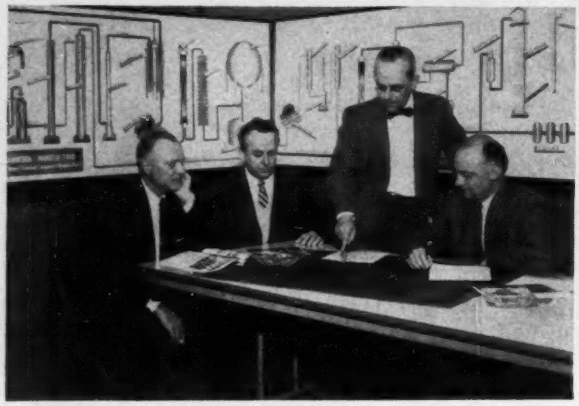
Representatives in principal cities throughout the world.

SPARKLER *horizontal plate* FILTERS

SPARKLER HORIZONTAL PLATE FILTER

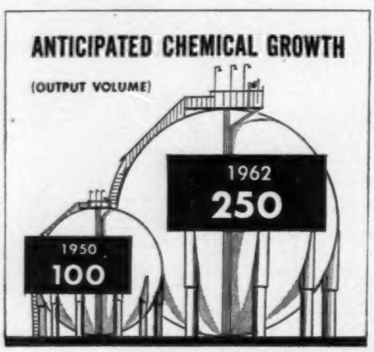






VICE PRESIDENT and plant manager J. G. Carriere (standing), discusses plant features with General Electric's H. F. Hemker, Grace Plant Superintendent Charles Dougherty, and G-E Service Engineer John Thrithart.

Grace Chemical* Installs Prepare New $20,000,000



BY 1962, it is expected that the chemical industry will more than double 1950 production levels. In graph, 1950 production equals 100.

Source: Manufacturing Chemists Assoc.

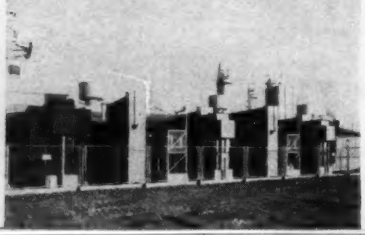
General Electric Engineering Services helped Grace Chemical design, install flexible electrical system to handle present and future power loads

**Grace Chemical Co., division of W. R. Grace & Co.*

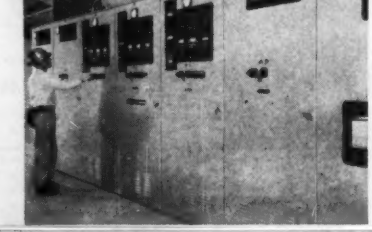
PLANNING NOW for future production is a major consideration in the fast-growing chemical and allied products industry. This booming industry is growing at the rate of about 7% per year (all industry growth averages only 3%) and the annual value of chemical products is now over 7% of the value of the nation's entire manufacturing output.

THE GRACE CHEMICAL COMPANY, a division of W. R. Grace & Co., anticipated growth and constructed the new ammonia-urea plant at Memphis, Tenn. Now in operation, the plant, described as one of the most modern in the industry, has an engineered electrical system that was planned to meet present

INCOMING POWER is "stepped down" by three G-E 7500-kva, three-phase, power transformers in the main substation. Whole plant uses grounded neutral system.



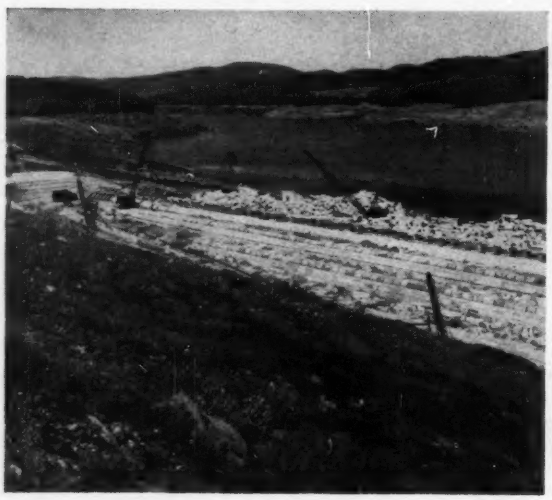
COST SAVINGS and operating convenience were obtained by locating 12,500-v, switchgear (below) inside, transformers (photo at left) outside the powerhouse.



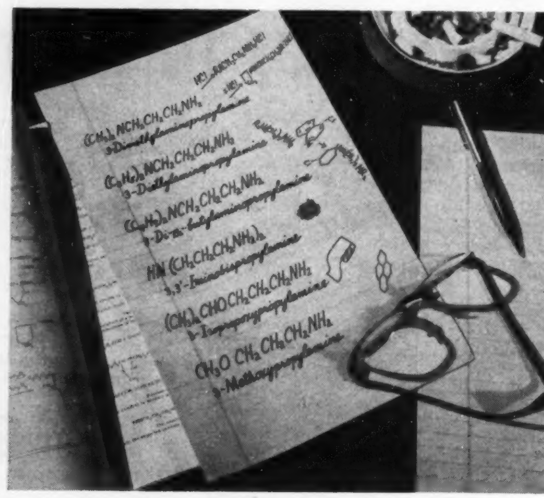
POWER is stepped down to 480 volts for the plant's process drives by this 1000-kva load-center unit substation, one of four installed in the plant.

Life on the Chemical Newsfront

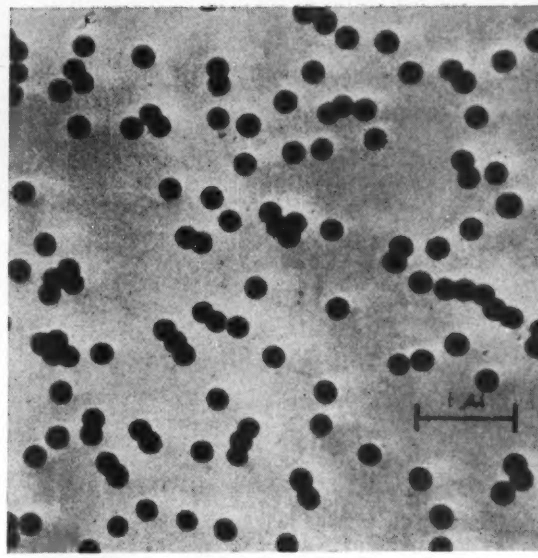
SILVER COMES CLEAN AS A WHISTLE with one quick dip in a properly formulated acidified thiourea solution, an ideal work-saving, silver-saving instant cleaner. The thiourea solution dissolves silver sulfide tarnish without the rubbing required by abrasive polishes and without loss of metallic silver other than that contained in the dissolved tarnish. Cyanamid's thiourea, a sulfur analog of urea, is a highly reactive intermediate also used in making black and white reproduction papers, liquid glues, fumaric acid, hair-waving lotions, pharmaceuticals, and in the treatment of nylon fiber and silvering of mirrors. **(Organic Chemicals Division)**



NEW WATER RESOURCES like the one above must be developed on an unprecedented scale to take care of growing municipal and industrial needs. A 90% increase in demand is forecast over the next twenty years, with industry taking the lion's share. To help quench this tremendous thirst, chemical means for purifying water also must be expanded. Cyanamid, a major producer of alum, widely used in water treatment and papermaking, is building a new liquid alum plant in Plymouth, N. C., to meet the growing need for this chemical in the South. Alum, an efficient coagulant, is used in water treatment and pH adjustment, and as a precipitant for rosin size. In liquid form, it can be handled with greater efficiency and economy. **(Industrial Chemicals Division, Dept B)**



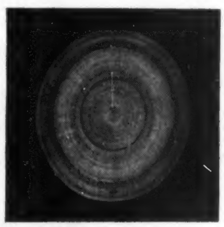
INTERESTING NEW PRODUCT POSSIBILITIES are offered by these six amines, derived from Cyanamid's acrylonitrile. Each has a propylamine group, but varies in the other substituent with corresponding changes in physical properties. As the substituent increases in each series, vapor pressure decreases, solubility in non-polar solvents increases, and activity in specific reactions varies. For example, dimethylaminopropylamine provides rapid cure for epoxy resins, while higher substituents offer greater pot life. Surface active agents produced by reaction with fatty acids make useful emulsifying agents for waxes and flotation agents. Possibilities also include use as intermediates for germicides, pharmaceuticals and dyestuffs. **(New Product Development, Dept. B)**

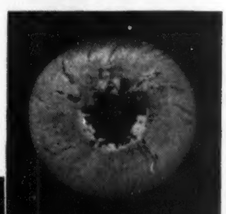


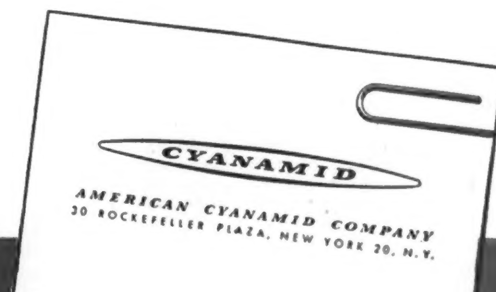
A NEW PIGMENT MAKES THE GRADE in exterior weathering exposures on Cyanamid's test fence. This time it's Cyan Green Toner 15-3100, a phthalocyanine green with high strength and excellent stability to light and weathering in exterior finishes. Recommended for paints, lacquers, automotive enamels, printing inks, plastics, floor coverings, synthetic textiles and roofing granules, Cyan Green Toner 15-3100 has excellent working properties. It disperses readily in coating formulations and is free from bodying. It is essentially non-bleeding in organic solvents, highly stable in both acid and alkaline media and does not migrate in organic media. (Pigments Division)

BETTER QUALITY CONTROL in the commercial production of rubbers, plastics and other polymers is one of the many benefits secured by selection of the proper surfactant for emulsion polymerization. AEROSOL® Surface Active Agents have shown excellent results as emulsifiers in producing uniform particle size, as shown above in an electron micograph of a styrene-butadiene latex, magnified 15,000×. The latex particles are very uniform in size and shape, ranging in diameter from 0.21-0.24 microns. The AEROSOLS also increase the rate of polymerization, stabilize dispersions during reaction and secure good heat, color and rub stability in the latex film. The versatility of AEROSOL Surface Active Agents has been demonstrated by their use in a variety of emulsion polymerization reactions. Since they vary considerably in ratio of polar to non-polar constituents, a selection is available for specific applications. (Industrial Chemicals Division, Dept. B)

FIGHTING ENGINE WEAR. Most new cars today are delivered with "break-in" oil containing zinc dithiophosphate. Major automotive manufacturers consider it the most effective wear-inhibiting additive, particularly in the valve-train mechanisms of modern V-8 high-compression engines. Notice the excellent condition of the test valve lifter (above) protected by oil containing AEROLUBE® 93-C Zinc Dithiophosphate, recently modified to give superior antiwear characteristics. The badly pitted valve lifter (below) received ordinary lubrication. AEROLUBE 93-C also controls oil oxidation and checks formation of corrosive peroxides and organic acids, extending bearing life and reducing engine maintenance. (Industrial Chemicals Division, Dept. B)





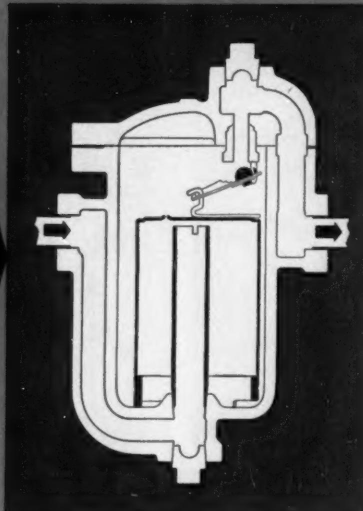


Additional information may be obtained by writing on your letterhead to the Division of American Cyanamid Company indicated in the captions.

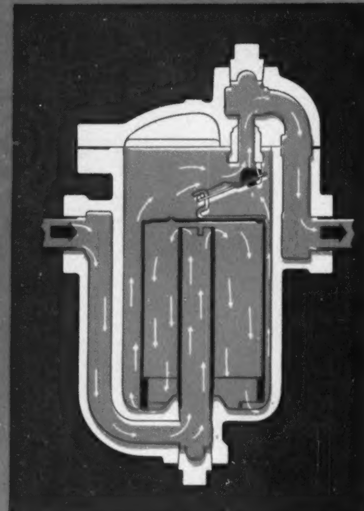
Building for the Future Through Chemistry

How Armstrong Trap Design

Picture of PROFITABLE TRAP PERFORMANCE



1. When trap is first installed, the inverted bucket is down and the valve is wide open. The large clearance between valve and seat minimizes restriction to condensate flow, contributing to large capacity.

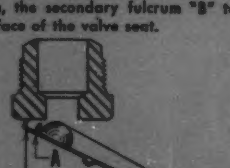


2. When steam is turned on, note how condensate (solid color) flows down between bucket and trap body, then up and out through orifice. Dirt is held in suspension and washed out when valve opens.

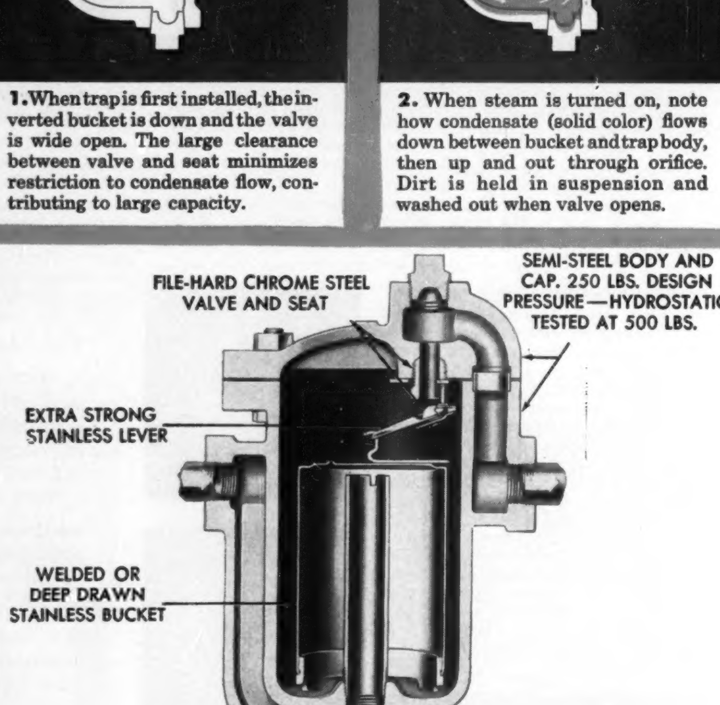
Two-Phase Leverage Provides High Capacity for Trap Size

Valve in closed position.

As bucket starts to sink, the lever fulcrums at "A", giving high leverage to open the valve against pressure. When valve is well open, the secondary fulcrum "B" touches the face of the valve seat.



Additional bucket travel results in fulcrum "B" becoming the pivot, permitting the valve to be opened wider so that restriction to flow of condensate is minimized.



Look at this trap. Only two moving parts. It's non-clogging, non-sticking, made of corrosion resistant materials. It will provide trouble-free service for years and years.

ARMSTRONG *Inverted*

ADVERTISEMENT—*This entire page is a paid advertisement* *Prepared by U. S. Industrial Chemicals Co.*

U.S.I. CHEMICAL NEWS

May-June ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1956

Teflon Can Be Bonded After Sodium Treatment

A new surface treating technique has been devised which enables Teflon to be bonded either to itself or to other materials. Until now the poor bonding characteristic of this corrosion resistant plastic has severely limited its application in many fields.

Here's how it's done! After solvent cleaning to remove surface grease and grime, the Teflon is dipped for a few seconds into a solution of 1% metallic sodium in liquid anhydrous ammonia. It is quenched in water, allowed to stand in the air, and then it can be cemented to aluminum, mild steel, wood or more Teflon with conventional adhesives. Bond strengths – both straight and shear tensile—are high enough for most applications.

Manufacturers of corrosion resistant tanks, pipes, ducts and valves who have been eyeing Teflon as a lining material for a long time now have a technique that will enable them to put many of their ideas into practice. Those who will be using metallic sodium for the first time in this application will find a great deal of valuable know-how in U.S.I.'s new 40-page book, "Handling Metallic Sodium on a Plant Scale." This book is available from U.S.I. without charge.

Methionine Helpful In Reducing Obesity

Methionine's ability to facilitate the mobilization and transportation of body fat during weight reduction has led to its use in a new drug formulation employed in treating obesity.

The new formulation contains amphetamine, phenobarbital, methycellulose, choline and vitamin B_{12}, in addition to DL-methionine. The methionine acts to relieve fatty infiltration of the liver, which, in cases of obesity, is already overburdened.

The new drug product was used in conjunction with a dieting regimen and was found to be well tolerated, convenient to take and therapeutically potent.

U.S.I. People Speak On Sodium At ACS Meeting

Metallic sodium was thoroughly discussed in a Symposium on "Handling and Uses of the Alkali Metals", at the 129th National Meeting of the American Chemical Society held at Dallas, Texas, in April. Among the papers was one entitled, "The Sodium Peroxide Production Story", by H. R. Tennant and R. B. Schow, describing the use of sodium in the manufacture of sodium peroxide at U.S.I.'s Ashtabula, Ohio plant. Another paper entitled, "Modification of Method for Determination of Sodium Monoxide in Sodium", by Dr. V. Hansley and R. A. Kolbeson of the U.S.I. Cincinnati Research Laboratory was also presented.

NEW EXTRA-WIDE POLYETHYLENE FILM CAN SOLVE MANY PROBLEMS IN CHEMICAL FIELD

Chemical Process Industries Welcome 22 Foot Width As Answer To Many Temporary Or Emergency Situations

Tough, flexible polyethylene film is now available in widths up to 22 feet. These newly available sizes offer simple, economical solutions to many of the problems that chemical processors face daily – in plants, pilot plants, and laboratories. Available from a number of film converters, the new, extra-wide films are made in a variety of heavy-gauge thicknesses and are folded into rolls of convenient width for easy handling.

Protects Personnel and Materials

Here are some examples of the use the film may be put to. Equipment may be sitting idle, or lying in storage, or in the process of being moved from one place to another – subject to dust, moisture or a chemically corrosive atmosphere. A polyethylene cover can be installed in minutes to provide protection. Or if solid raw materials have to be stored before use in a spot where conventional storage facilities are inadequate, a processor can spread the polyethylene film, dump the material on it, then cover the whole with another sheet of tough, impenetrable polyethylene. Rock salt piles for winter highway use are stored that way in some northern states. And bulk shipments of raw materials by gondola rail car or river barge are now being covered with polyethylene film to protect against moisture.

If an operation is conducted in the open air and weather is cold or stormy, a temporary polyethylene housing over the whole process, or part of it, can keep the operators warm and dry. As a matter of fact, this film is extensively used in new construction to wall in entire buildings as a protection for workers during the winter. A chemical plant can put it to the same use, not only during construction or maintenance work, but perhaps after a small explosion or fire leaves a building partly exposed.

MORE

Pulmonary Edema Treated Successfully With Alcohol

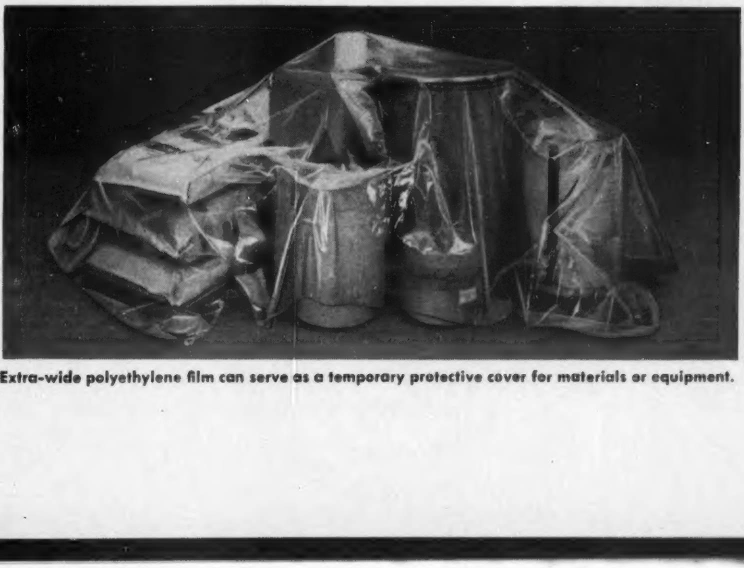
Pulmonary edema, an acute and often fatal fluid congestion of the lungs, which sometimes occurs immediately after surgery, is reported to be treated successfully with ethyl alcohol vapor.

This development was reported in an article entitled, "Alcohol Inhalation in the Treatment of Acute Pulmonary Edema in the Immediate Post-Operative Period."* In most of the cases described, inhalation of 95% ethyl alcohol vapor produced immediate and dramatic recovery, with no apparent harmful effect.

In relieving pulmonary edema, ethyl alcohol reportedly reduces surface tension and acts as an anti-foaming agent. In severe cases of edema, foam is formed in the respiratory passages, interfering with oxygenation. This suffocation in turn increases the formation of foam. The alcohol vapor interrupts this vicious cycle by modifying the surface tension of the fluid, thereby reducing the amount of foam and permitting oxygen to enter the lungs to further alleviate the condition.

The vaporized alcohol can be administered with standard anæsthesia equipment, available in all operating rooms. Because most cases of pulmonary edema occur during or immediately after surgery, the convenience of this method of administering the alcohol contributes greatly to the success of the new technique.

*R. Weyl, Illinois Medical Journal, *108*, No. 5, November (1955).



Extra-wide polyethylene film can serve as a temporary protective cover for materials or equipment.

May-June ★ **U.S.I. CHEMICAL NEWS** ★ 1956

CONTINUED Polyethylene

And where a pipe starts leaking at an upper level, a polyethylene tent over a working area below can protect personnel until repairs can be made.

In the pilot plant or laboratory, perhaps two or three investigations are being carried out in the same room, and dust from one threatens to contaminate the other. A temporary polyethylene room divider can be quickly installed to separate the activities.

Lines Kettles and Bins

There are also the many short-term lining services that polyethylene can perform to prevent materials from becoming contaminated, to save wear and tear on equipment, or to make ordinary vessels temporarily do the work of corrosion resistant equipment—such as lining pilot plant kettles for a special job involving corrosive materials, or lining bins containing dry materials to protect against moisture.

Because polyethylene film is light, tough, flexible, easy to handle, and inexpensive, and because it keeps out cold and moisture and lets in light, its potential applications in the chemical industry—now that it can be obtained as a wide film—are almost limitless. Plant, and especially pilot plant supervisors, would do well to keep this film in mind as a possible way out of some of those inevitable emergency situations.

While U.S.I. does not supply the film, it does make polyethylene resin, from which the film is made. Your Editor is anxious to hear of cases where you have been able to put polyethylene to work in your chemical process.

Plastics Exposition In New York This June

New York City's brand new Coliseum will play host to the 7th National Plastics Exposition, June 11-15, 1956. Over 225 individual companies plan to exhibit their products to an expected 20,000-plus crowd. U.S.I.'s PETROTHENE® Polyethylene resin will be featured in Booth 710 located near the southwest corner of the second floor. Also exhibited will be "U.S.I. Isosebacic" acid, a promising intermediate for many plastic uses. Technical and sales personnel familiar with both the polyethylene and the "U.S.I. Isosebacic" acid, as well as those familiar with other U.S.I. solvents of interest to the plastics industry, will be in attendance at the booth. They will be ready to discuss these products with plastics manufacturers and users.

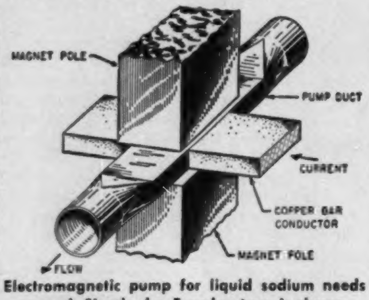
Sodium Pump Has No Moving Parts

For its work with liquid metals, the Atomic Energy Commission has sponsored development of several types of electromagnetic (EM) pumps for moving liquid sodium and the sodium-potassium alloy known as NaK.

Operation of these pumps is based on the high electrical conductivity of sodium. An EM pump operates on the same principle as an electric motor, but instead of iron moving in an electric field the sodium moves in a similar electric field. Thus, the sodium stream acts as the moving part of the motor and it is pumped forward.

Advantages of electromagnetic pumps are: they can be totally sealed; have no moving parts; can be mounted in any position; permit easy flow control. Both a.c. and d.c. types are used, depending on the application.

Sodium can, of course, be transferred by other methods, as described in U.S.I.'s recent booklet, "Handling Metallic Sodium on a Plant Scale." It can be transferred by vacuum, by positive displacement pumps, or by centrifugal pumps—and the final choice will depend on specific operating conditions.



Electromagnetic pump for liquid sodium needs no seal. Simple d.c. Faraday type is shown.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

A starting fluid for diesel and gasoline engines now comes in a pressurized can. Designed for cold or damp weather, the product reportedly gives quick, sure starts down to 65° below 0°F., can withstand heat up to 180°F. safely. **No. 1150**

A polyethylene glue dispenser resembling a pen has just been introduced in this country. The new unit will release one dot of rubber cement at a time, holds 5000 dots. Like a pen, it can be refilled with a disposable cartridge. **No. 1151**

Alcohol and solvent users can now obtain wall charts for determining the contents of 55-gallon drums at various temperatures by stick measurement. They are useful for making approximate measurements with minimum effort. **No. 1152**

A high-temperature pressure gauge has been developed, reputed to give continuous accurate readings under long exposure to high heat and radiation. It is manufactured in a wide variety of materials to resist any liquid or gas. **No. 1153**

A new C-18 unsaturated fatty diol is offered commercially as an intermediate for cosmetics, polyester modifiers, surfactants, quaternary derivatives. The compound has 1 double bond, OH groups on the 1st and 12th carbon atoms. **No. 1154**

A small hand pump made entirely of polyethylene is now marketed which delivers a gallon of liquid in a few seconds. It is chemically inert and very durable mechanically. The pump comes in various barrel lengths and mountings. **No. 1155**

A sodium alloy slug to prevent oxidation of motor oil has been placed in an air-and-water-free fitting in the line ahead of the oil filter. It is claimed that cars fitted with this device have gone 20,000 miles without oil deterioration. **No. 1156**

Heavy rare earth oxides in purities to 99.9% are now available in substantial quantity. Included are yttrium, samarium, gadolinium, ytterbium, dysprosium, erbium, thulium. Large uses have been found in metallurgy, optical polishing. **No. 1157**

An amine-type hardener for epoxy resins, recently announced, permits clear castings of up to 40 lb. in a single pour. Used at 15:100 parts by weight of epoxy, resulting resin may be cured at 140-200°F. in up to 15 hrs. **No. 1158**

Polyethylene plugs to protect holes during finishing of metal parts are now being made in all standard tap sizes from No. 1 to ½ in. The plug is removed after surface finishing, leaving a clean hole of the original dimension. **No. 1159**

PRODUCTS OF U.S.I.

POLYETHYLENE RESINS:

PETROTHENE® 100 Series—high quality resins for uses demanding outstanding properties.

PETROTHENE 200 Series—general purpose resins for extrusion, injection, compression molding and paper coating.

PETROTHENE 300 Series—resins for wire covering and electrical insulation applications.

OTHER PRODUCTS:

Alcohols: Ethyl (pure and all denatured formulas), Normal Butyl, Amyl, Fusel Oil; Proprietary Denatured Alcohol Solvents SOLOX®, FILMEX®, ANSOL® M, ANSOL® PR.

Inorganic Chemicals: Ammonia, Caustic Soda, Chlorine, Metallic Sodium, Sodium Peroxide, Sulfuric Acid.

Esters, Ethers and Ketones: Normal Butyl Acetate, Dibutyl Phthalate, Diethyl Carbonate, Diethyl Oxalate, Ethyl Acetate, Ethyl Ether, Acetone.

Intermediates and Fine Chemicals: Acetoacetarylides, Ethyl Acetoacetate, Ethyl Benzoylacetate, Ethyl Chloroformate, Ethylene, Ethyl Sodium Oxalacetate, Sodium Ethylate solution, Urethan USP (Ethyl Carbamate).

Animal Feed Products: Calcium Pantothenate, Choline Chloride Products, Curbay B-G® 80, Special Liquid Curbay®, DL-Methionine, Niacin USP, Riboflavin Concentrates, Vitamin B_{12} and Antibiotic Feed Supplements, Vacatone® 40, Vitamin A, D_3 and K_3 products.

Pharmaceutical Products: DL-Methionine, N-Acetyl-DL-Methionine, Riboflavin USP, Urethan USP, Intermediates.

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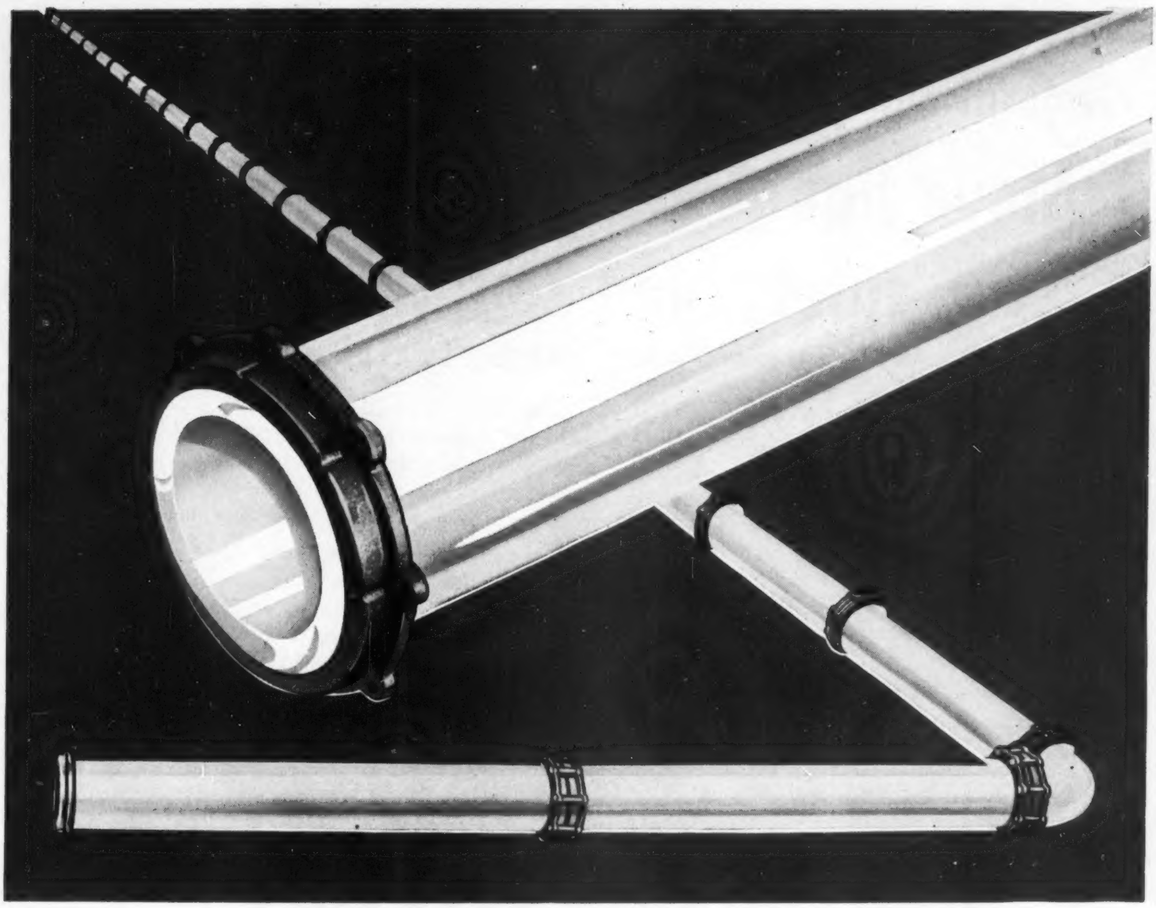
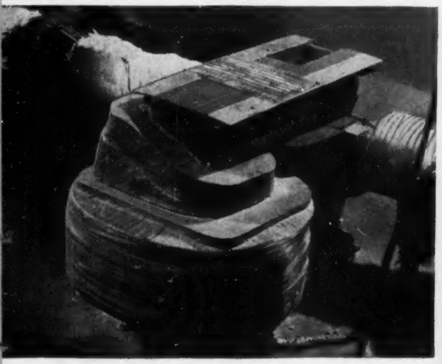


LIQUID METAL LOOP tests sodium potassium (NaK) in a G-E electromagnetic pumping system for use as heat-transfer agent. Loop's a-c EM pump (below) operates at 600 degrees F with capacity of 30 gallons per minute. Magnetic flowmeter (left of pump) measures flow externally, providing greater safety.



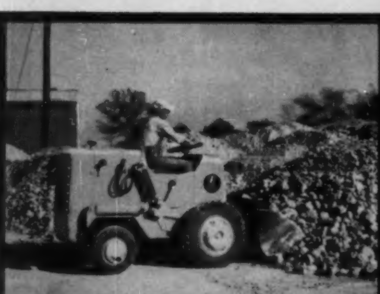
Bigger Loads...

Less Spillage

...more Productive capacity

It's the amount of bulk-material *delivered* per shift or per day that counts, and the new model HA "PAYLOADER" tractor-shovel has proven in plant after plant that it consistently delivers more material faster and at less cost than heavier machines with larger engines.

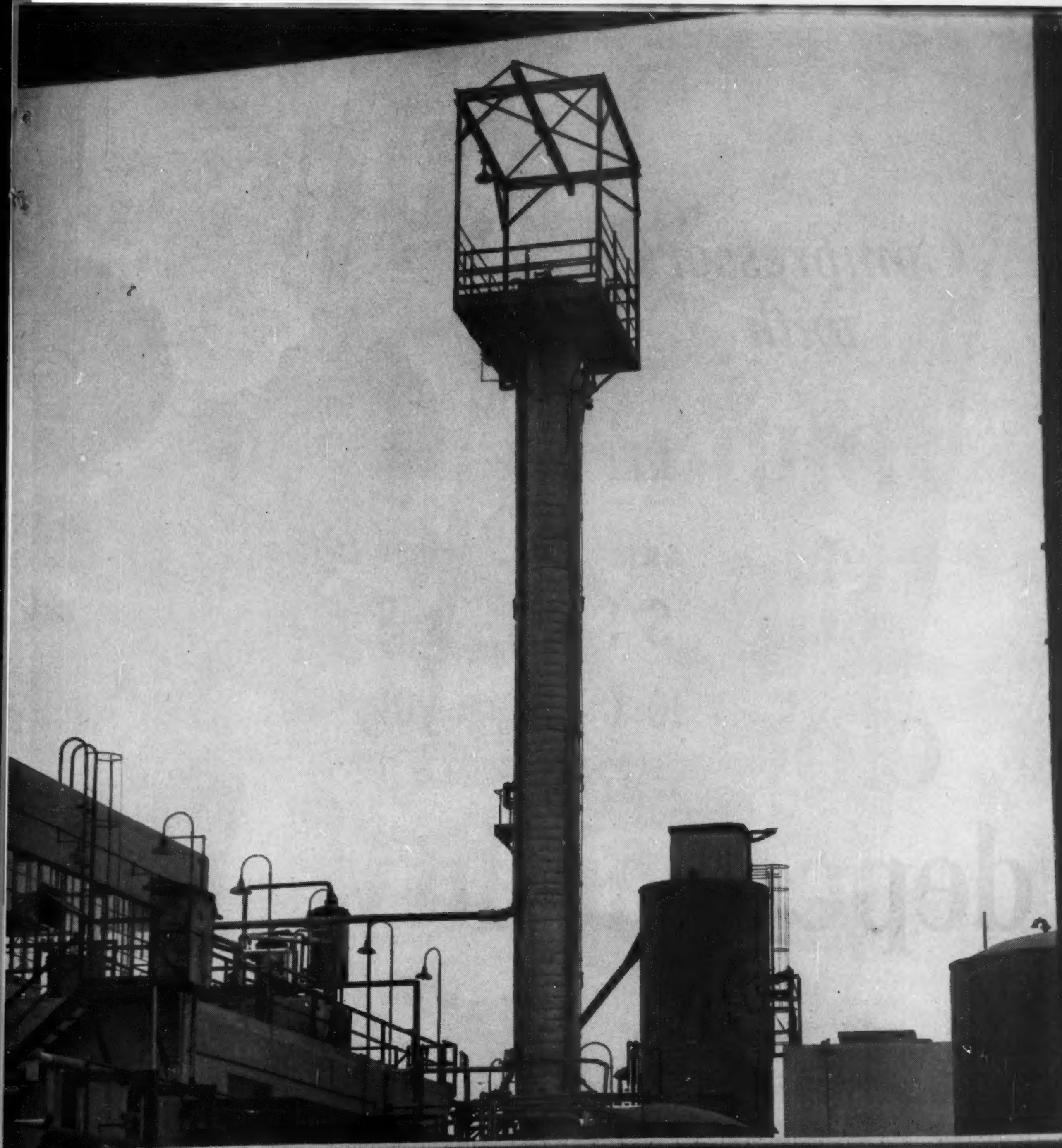
A big reason for this superior performance is the roll-back bucket action that scoops up heaping loads and carries them *low*. Another, is the exclusive built-in hydraulic shock absorber that cushions the load during travel — reducing spillage and allowing higher travel speeds.



Gets more: Forty degree tip-back of bucket at ground level gets heaped loads.

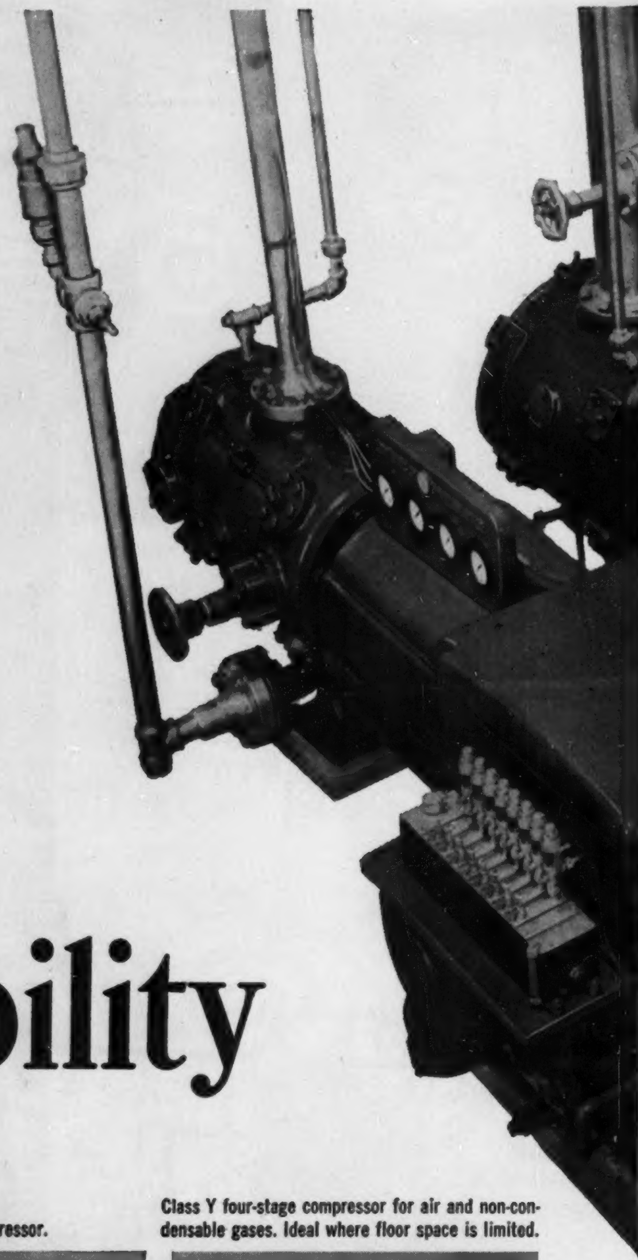
Keeps more: Maximum bucket tip-back is reached *before* bucket is raised—less spillage at pile.

Carries more: Exclusive hydraulic shock absorber cushions the load during transport — less spillage while carrying.



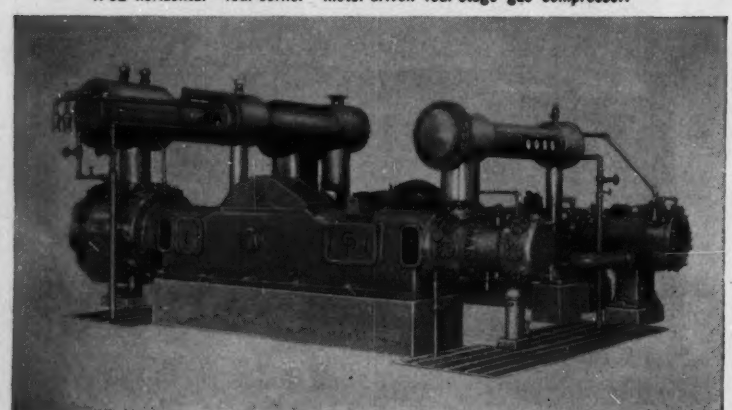
The fat splitter is 65 feet high. It is lined with 7/64" Stainless Steel.

UNITED STATES STEEL

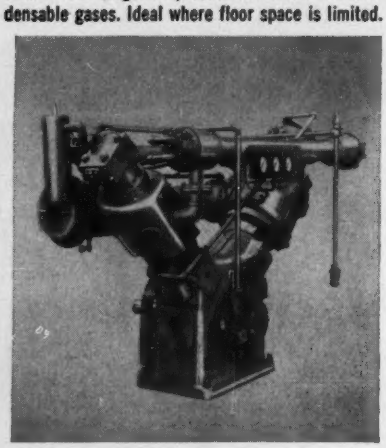


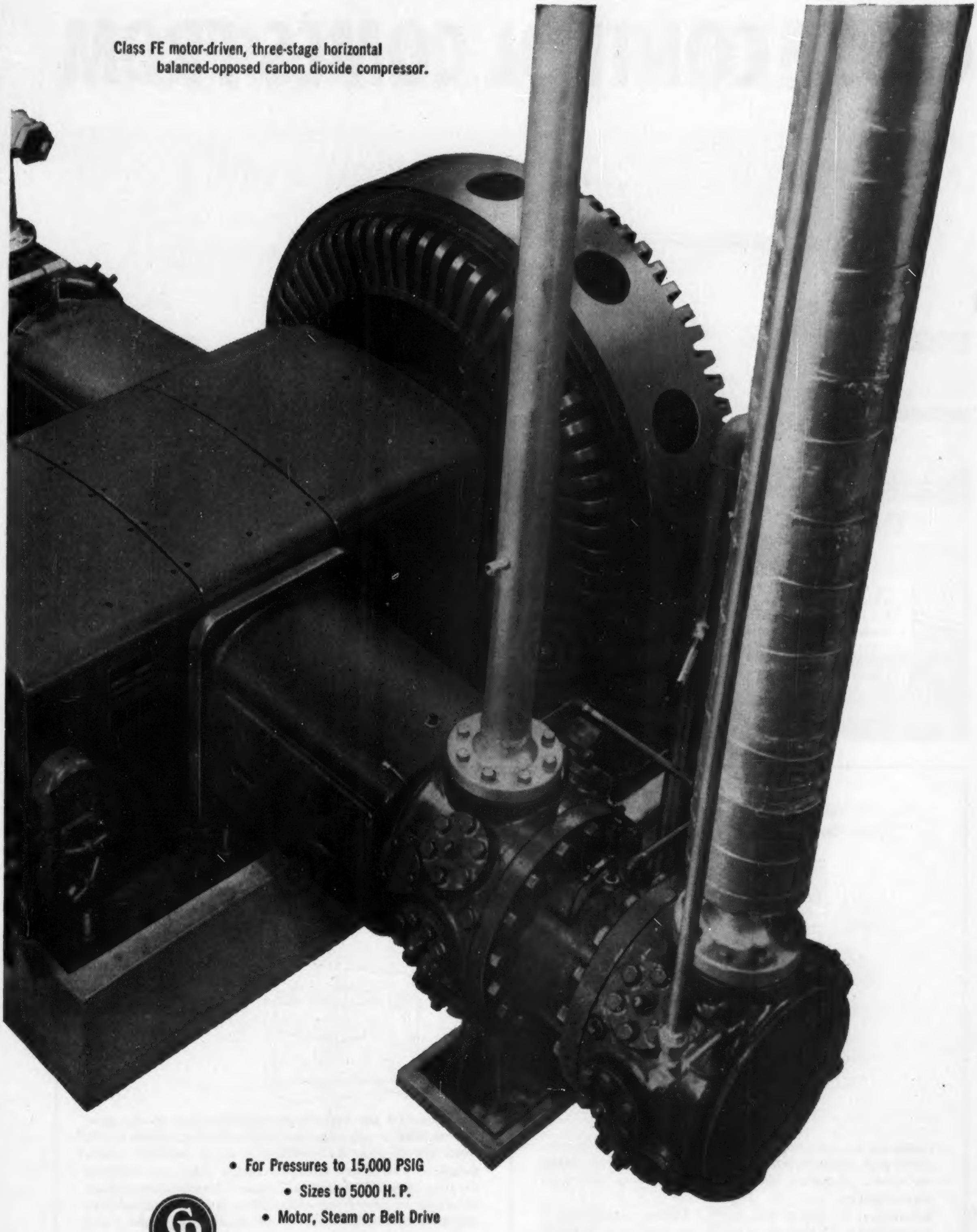
Compressors with 'round the clock dependability

H-CE horizontal "four-corner" motor-driven four-stage gas compressor.



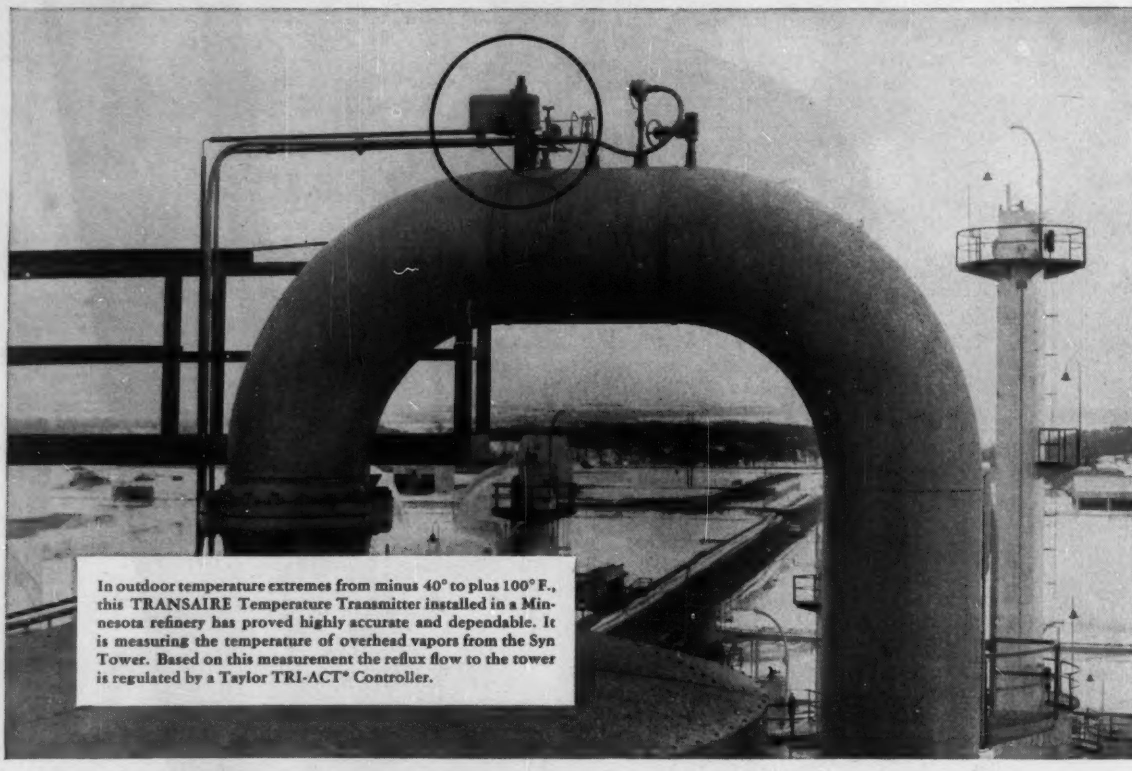
Class Y four-stage compressor for air and non-condensable gases. Ideal where floor space is limited.





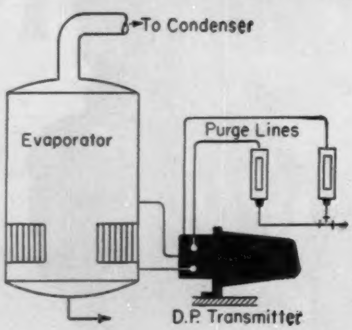
Class FE motor-driven, three-stage horizontal balanced-opposed carbon dioxide compressor.

CLOSE CONTROL COMES FROM



In outdoor temperature extremes from minus 40° to plus 100° F., this TRANSAIRE Temperature Transmitter installed in a Minnesota refinery has proved highly accurate and dependable. It is measuring the temperature of overhead vapors from the Syn Tower. Based on this measurement the reflux flow to the tower is regulated by a Taylor TRI-ACT* Controller.

AUTOMATIC PURGING OF SUSPENDED SOLIDS

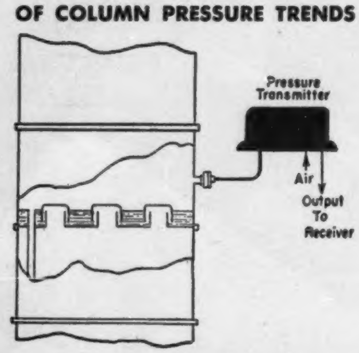


Problem: To obtain uninterrupted liquid level measurement and control where solids in suspension could settle out, plugging lead lines and causing errors in measurement.

Solution: The use of the 333RD Differential Pressure Transmitter. Dual taps provide for complete flushing of the instrument body as well as the lead lines.

Result: Consistently high accuracy. Flushing of manometer and lead lines cuts maintenance to a minimum. Evaporator efficiency is kept at a uniformly high level.

QUICK DETECTION OF COLUMN PRESSURE TRENDS



Problem: To get highest possible product purity consistent with production economy. This requires quick detection of pressure trends over a very narrow range.

Solution: The short, shiftable range spans (as short as 20 psi) of the TRANSAIRE Pressure Transmitter permit selection of operating range by a simple screw-driver adjustment. Its high order of sensitivity enables the operator to detect minute changes of pressure.

Result: Close control, because the minute pressure trends are practically instantaneously detected and transmitted to the controller and receiver. This means higher yield of a purer product, also great flexibility in changing to different product requirements.

ACCURATE MEASUREMENT –

Check these examples of Taylor Transmitter accuracy and versatility

THE TRANSAIRE* line of force-balance transmitters for temperature, pressure and differential pressure has created new standards in recent years in the measurement of dynamic temperatures and pressures . . . and now the new TRANSET* Potentiometer Transmitter has broadened the base of measurement to accurately measure temperatures within limits of minus 320°F. to plus 3272°F.

In the examples shown below, the transmitters' high degree of sensitivity to minute changes in temperature, pressure or differential pressure is the solution to the problem of accurate measurement . . . and consequent close control.

For *speed of response,* for *dependable operation,* for *simple maintenance,* for *wide rangeability and flexibility,* these instruments have proved themselves unsurpassed in field performance.

*Trade Mark

Ask your Taylor Field Engineer or write for **Bulletin 98097** (for TRANSAIRE Temperature, Pressure or Differential Pressure Transmitters) or **Bulletin 98262** (for TRANSET Potentiometer Transmitter). Taylor Instrument Companies, Rochester, N.Y., or Toronto, Canada.

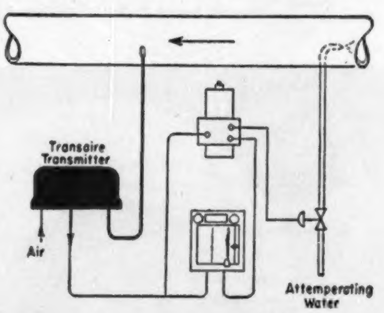
Taylor Instruments

MEAN

ACCURACY FIRST

IN HOME AND INDUSTRY

MEASUREMENT OF RAPID TEMPERATURE CHANGES IN DESUPERHEATER

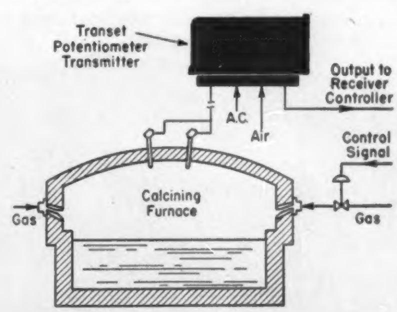


Problem: Steam at high temperature, as with any gas temperature measuring problem, has poor heat transfer characteristics, making it difficult to measure dynamic temperatures.

Solution: The low heat capacity of the cigarette-size bulb of the TRANSAIRE Temperature Transmitter (made possible by the force-balance system), and SPEED-ACT* compensation for the rugged well required, give unprecedented speed of response to temperature changes under these adverse conditions.

Result: Smooth efficient operation, and greater protection to expensive equipment in subsequent processing steps.

PRECISE CONTROL OF HIGH TEMPERATURE CALCINING FURNACE

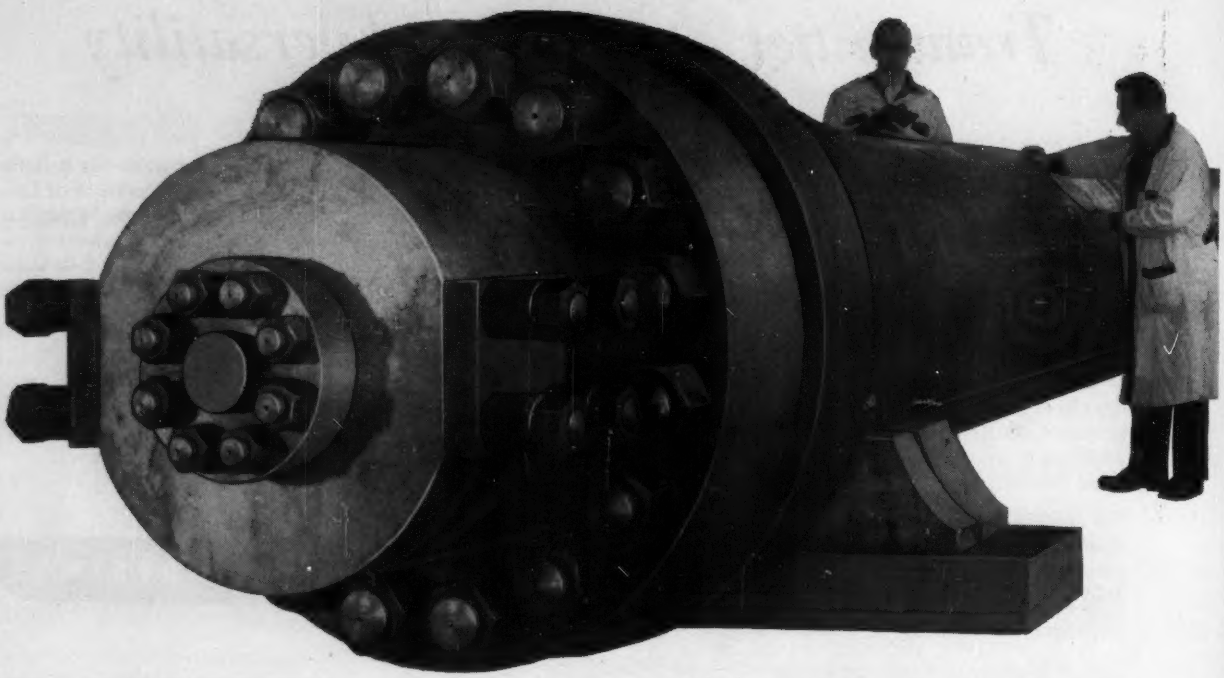


Problem: Optimum operating temperature too high for conventional platinum vs. 13% rhodium platinum thermocouples and local conditions too stringent for radiation pyrometers. Reliable control necessary for protection of furnace.

Solution: New 5-20 platinum rhodium thermocouple with inert impervious protection tube gives precise and reliable measurement of temperature. TRANSET Potentiometer Transmitter has necessary zero suppression and rangeability to transmit control operating range of temperature to TRANSET control system on gas burners.

Result: Precise control assures prolonged life of furnace with maximum throughput and quality of product.

8000 pressure vessels ...

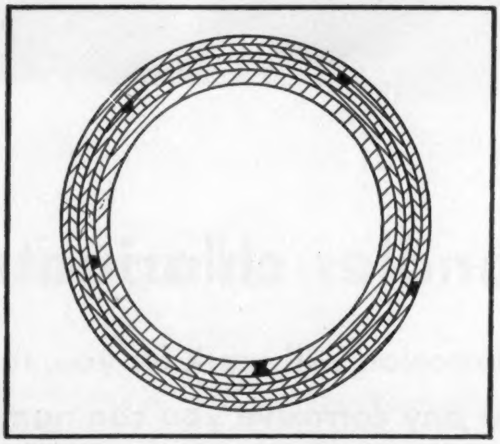


MULTI-LAYER AMMONIA CONVERTER
Built for operating pressures of 12,500 psi. . . . test pressures of 18,750 psi.
Wall thickness 9 15/16 in. . . . I. D. 25 3/16 in.
Overall length is 44 ft. Weight 238,000 lbs.

SAFETY — Nearly 8000 MULTI-LAYER vessels in operation — and not a single failure — certainly convincing proof of the safety inherent in this unique A. O. Smith design. To further prove operating safety, we have actually tested many full-scale, high-pressure MULTI-LAYER vessels to destruction. In every case, vessels rupture without shattering or fragmentation.

...8000 reasons why you can depend on exclusive MULTI-LAYER CONSTRUCTION

FOR SAFETY
FOR ECONOMY
FOR FLEXIBILITY



ECONOMY — Savings start with fabrication. Instead of using thick plate in a single wall, MULTI-LAYER vessels are built up from concentric layers of relatively thin steel plate . . . progressively wrapped, tightened and welded together around an inner, pressure-tight cylinder. No need for costly stress-relieving in field assemblies. And for corrosive operations, only the inner shell requires special alloys.

FLEXIBILITY —With MULTI-LAYER, there's no limitation of size or weight for your vessel design. You can design for higher pressures, too. Walls can be made stronger simply by increasing the strength of the steel used or by adding more layers. Since shell sections can be welded together in the field, vessel length is not limited.

See how A. O. Smith's exclusive MULTI-LAYER construction can provide safety, economy and flexibility in your own operations. Write our nearest office. We'd be happy to provide more detailed information about MULTI-LAYER construction for high-pressure vessels.

Through research ...a better way

A.O.Smith
CORPORATION

PROCESS EQUIPMENT DIVISION

Milwaukee 1, Wisconsin

Chicago 4, Illinois • Cleveland 15, Ohio • Dallas 2, Texas • Denver 2, Colorado • Houston 2, Texas • Los Angeles 22, California • Midland 5, Texas • New Orleans 12, Louisiana • New York 17, New York • Pittsburgh 19, Pennsylvania • San Francisco 4, California • Seattle 1, Washington • Tulsa 3, Oklahoma • Washington 6, D. C.

INTERNATIONAL DIVISION: Milwaukee 1, Wisconsin

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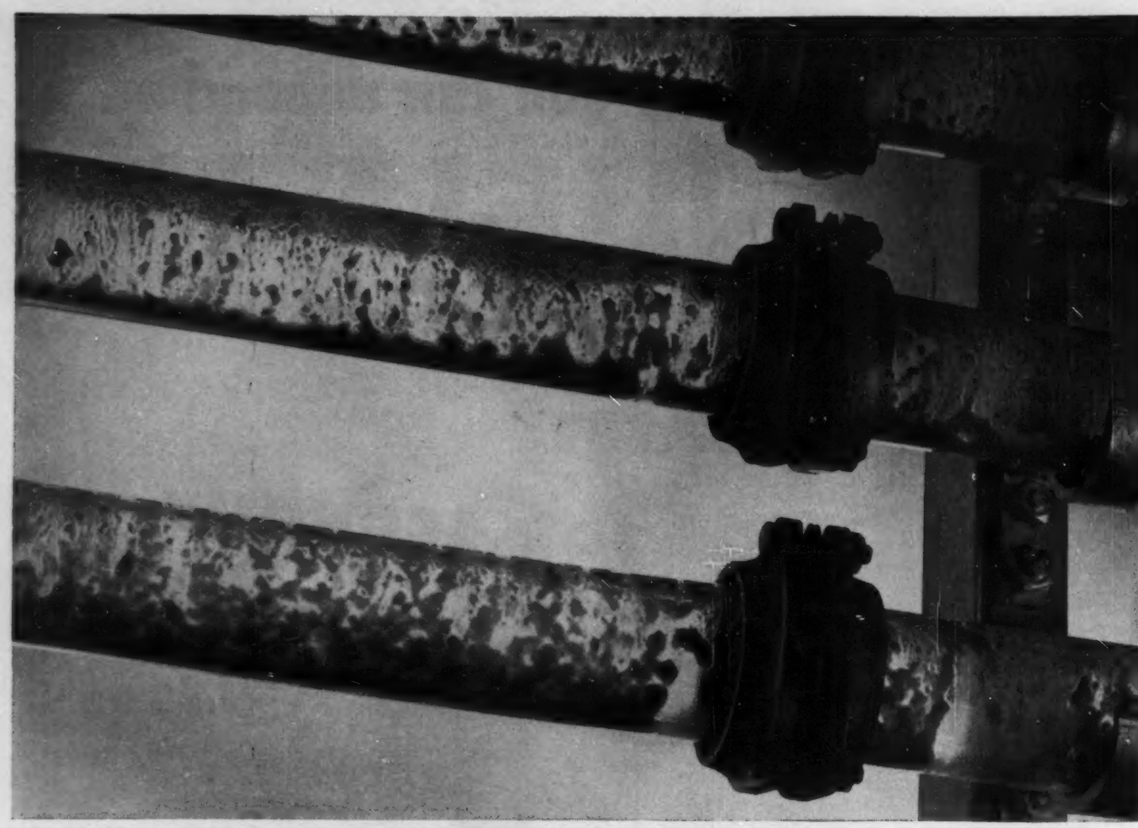


This plant handles chlorinated

Its proved answer to corrosion will work for you, too ...with almost any corrosive you can name

Are the corrosives you use as vicious in their attack on pipelines as hot chlorinated hydrocarbons? Or strong-water HC1 dilutions?

These chemicals cost the Thiokol Corporation large amounts of money at their Moss Point, Miss. plant when it was started. The corrosion rate was high. Pipeline replacement was frequent. In short, there were serious corrosion problems.

Then, after testing many kinds of pipe, Thiokol installed PYREX brand glass pipe.

The tests had indicated that PYREX pipe presented the most economical solution for handling the corrosives involved.

Maintenance costs reduced

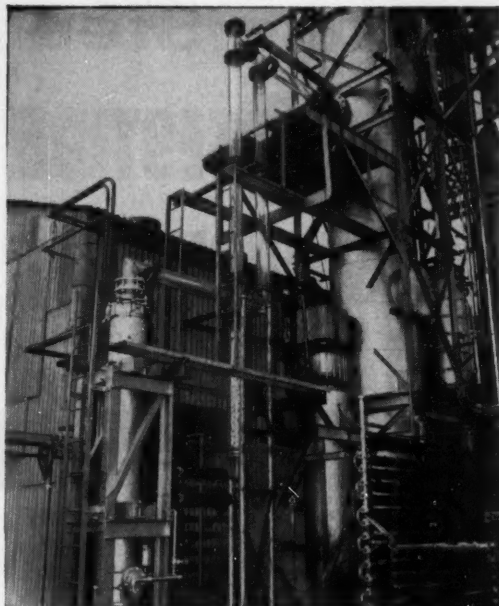
After four years of steady service, these lines look and operate like new. They are free of corrosion and erosion.

Cost figures over the four year period still indicate that PYREX pipe is the most economical installation for this exposure. At Thiokol, maintenance is very simple and cost is reasonable.

Thiokol Corporation avoids cleaning trouble

In this process, paraformaldehyde occasionally builds up. This could be a real threat in any opaque pipe, but it's visible in glass. As soon as it collects, Thiokol flushes it out with steam.

Easy cleaning is a prime characteristic of PYREX pipe. Suppose you



Are your layouts complex? You can plan a system of glass pipe as intricate as you need, because you can get all the standard fittings, elbows and turns industrial pipe fitting calls for. You can get PYREX pipe in 1", 1½", 2", 3", 4" and 6" I.D.'s in standard lengths up to 10 feet.

These PYREX pipelines have withstood the attack of hot chlorinated hydrocarbons and strong solutions of HC1 and water for as long as four years. Pump vibration adds another factor of severe use. Yet, with all this, glass pipe is, for all useful purposes, as new today as it was four years ago.

hydrocarbons . . .

want to use the same lines for incompatible fluids. You clean glass lines at change-over time simply by flushing them with low-pressure steam, hot water, detergent solution, or, in some cases, with dilute HC1. No down time, no difficulties. And you *see* when lines are clean.

Easy, low-cost installation

The men who regularly install your piping can install glass pipe easily, even if they've never worked with it before. Thiokol's own men cut and assemble PYREX brand pipe. The field kit makes this an easy job.

Your corrosion problem

No matter what corrosives you transport, except HF and hot concentrated alkalis, PYREX brand glass pipe will stop your corrosion problems.

One of the best ways to really know the advantages of glass pipe is through knowing a user. To meet one near you, write us and we'll try to set up a visit. In the meantime, we can send you informative literature. Send the coupon.

CORNING GLASS WORKS
16 Crystal Street, Corning, New York

Gentlemen: I would like to see an installation of PYREX pipe. Please contact me to make arrangements. ☐

My corrosion problems involve these chemicals ....

....

Please send me the following literature: Bulletin EA-1, "PYREX Pipe in the Process Industries" ☐; Bulletin EA-3, "PYREX brand 'Double-Tough' Glass Pipe and Fittings Catalog" ☐; Bulletin PE-3, "Installation Manual for PYREX Pipe" ☐.

Name ....

Title ....

Company ....

Street ....

City ....

Zone .... State ....

CORNING GLASS WORKS, CORNING, N. Y.
16 Crystal Street

Corning means research in Glass

Drums provide

DURING HANDLING, STORAGE

Republic Steel Corporation, manufacturers of a complete line of light and heavy gage Steel Drums, has always specialized in the needs of the chemical industry.

For example, in the light class of I.C.C.-17E, 17H and 17C, either Tight End or Full Removable Head, we offer a complete service in high bake lacquer linings to protect many difficult-to-hold products. Or, we can supply drums hot dip galvanized or hot dip tinned.

In the heavy gage class, our drums comply with I.C.C.-5, 5A, 5B and 17F, as well as some of the I.C.C.-6 series. Depending on specification and service involved, we produce drums of 55-, 30- and 20-gallon capacities, from 16 to 12 gage in hot rolled carbon steel. In addition, we operate our own hot dip galvanizing and hot dip tinning facilities.

In this range of operations we offer a complete chemical industry service for shipping and storage, plus decorating facilities for both bodies and heads.

Finally, we manufacture a complete line of Steel Packages from 3½- to 20-gallon capacity, from 26 to 20 gage, in plain steel, decorated, and with special high bake linings when required.

Make sure your materials get the protection they deserve. Specify Republic Steel Drums. For further information, mail coupon for catalog ADV-621, today.

PROTECTION AGAINST CORROSION resulting in contamination or loss of chemically active liquids is assured when you specify ENDURO Stainless Steel Tubing. In addition, ENDURO's great strength and heat resistance make it ideal for processes requiring fluid materials handling at high temperatures and pressures. For further details, clip and mail coupon.

PROTECTION OF ELECTRICAL CIRCUITS against highly corrosive fumes, gases, vapors as well as mechanical damage is provided by Republic Dekoron-Coated ELECTRUNITE® E.M.T. It's lightweight and easy to handle. Properly installed, this plastic-coated electrical raceway provides long-lasting protection from one end of your circuit to the other. Send coupon today for complete information.

ENDURO® STAINLESS STEEL PROTECTS purity and quality of the powdered material produced by this giant spray-drying unit. ENDURO is ideal from a maintenance standpoint, too. It resists abrasion and erosion and is easily kept clean and sanitary. It neither affects nor is affected by most chemical, food and drug products.

STEEL

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Cleveland 27, Ohio

Please send catalog ADV-621
Please send further information on:
☐ ENDURO Stainless Steel
☐ Dekoron®-Coated E.M.T. ☐ Stainless Steel Tubing

Name________ Title________
Company________
Address________
City________ Zone____ State________

AMMONIA

at Grace Chemical Company*

Huge plant at Memphis uses pressures up to 12,000 psi to produce 250 tons of anhydrous ammonia, 150 tons of urea a day

Compression plays a vital role in ammonia production and the nine Ingersoll-Rand compressors totalling 22,100 horsepower at the Grace Chemical Company plant are the backbone of their ammonia-urea processing.

Each of three 4000-hp units handles three separate gases at varying intake and discharge conditions in preliminary processing.

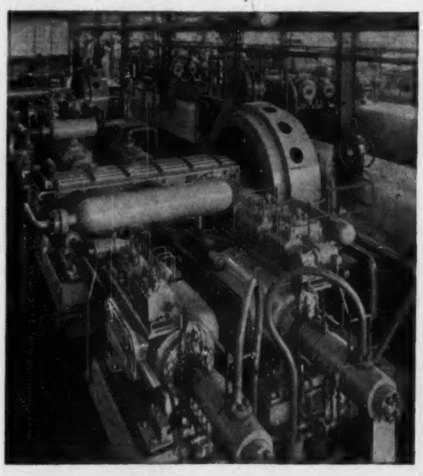
Three 3000-hp compressors boost the hydrogen-nitrogen mixture from 275 to 12,000 psi in five stages to feed the Casale converters.

A 900-hp HHE compressor discharges carbon dioxide at 3215 psi for combining with the ammonia to form urea by the Pechiney process.

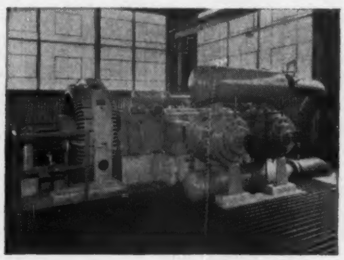
For a detailed description of the operation of this Grace Chemical Company synthetic ammonia plant, send for a copy of Form 3223.

This installation is typical of process plants of all types that use dependable Ingersoll-Rand compressors — whether reciprocating, centrifugal or combinations of both. Plant operators have found that these machines can be counted on to do their jobs efficiently, and with a minimum of attendance and upkeep. Form 3132 illustrates many such processes. Send for your copy.

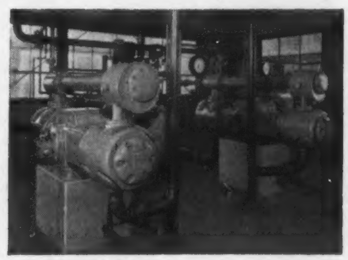
*Division of W. R. Grace & Co.



Each of these three 3000-hp HHE synthesis gas compressors supplies its own Casale converter with a hydrogen-nitrogen mixture at pressures ranging from 9000 to 12,000 psi, depending on the operating conditions.



Carbon dioxide, compressed to 3215 psi by this 900-hp HHE compressor, is combined with ammonia at 350°F in the Pechiney process, forming urea.



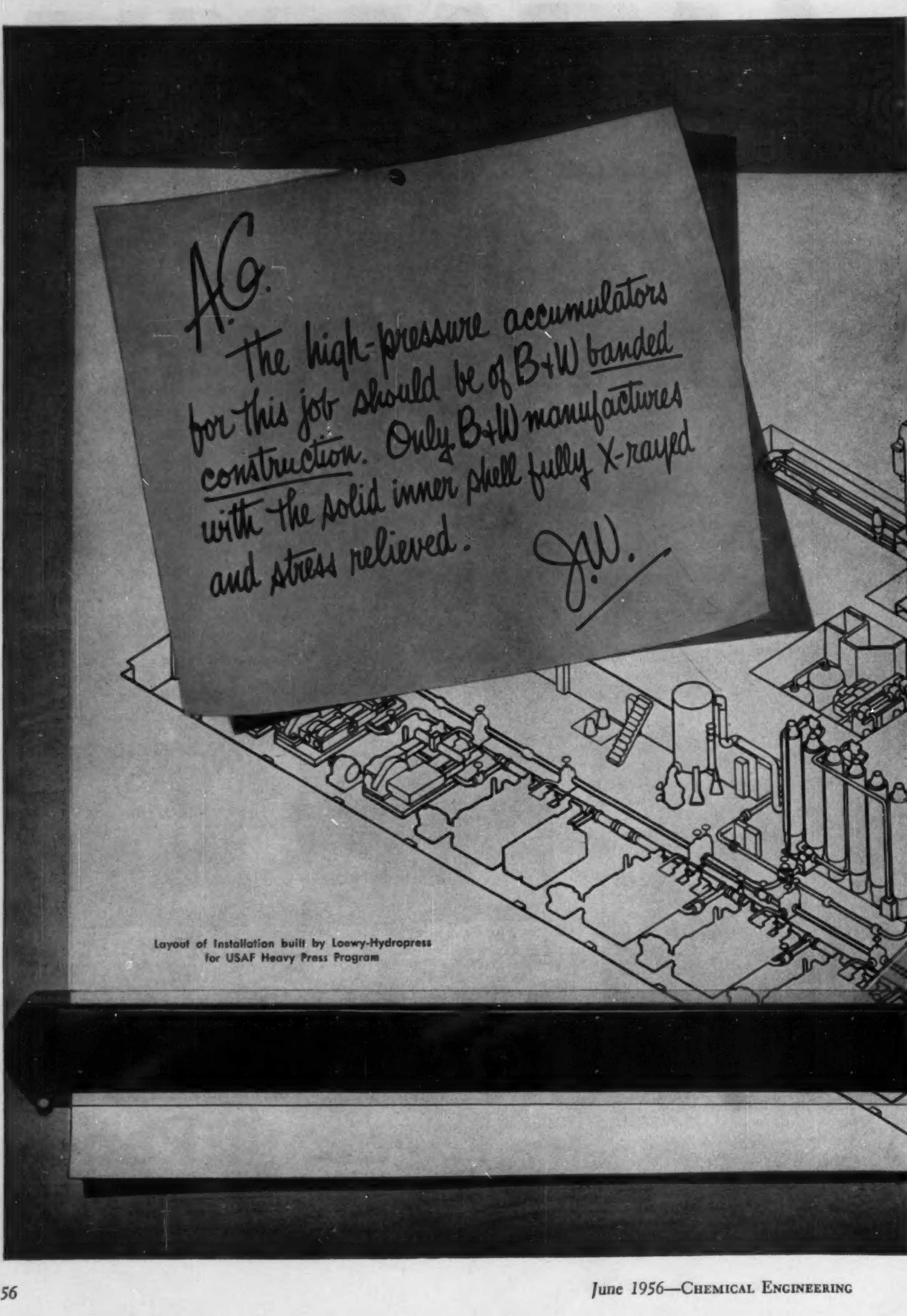
These two 100-hp PHE compressors discharge air at 100-115 psi. Pressure is reduced to 60 psi for general plant service and to 15-20 psi for operating automatic control instruments.

Ingersoll-Rand

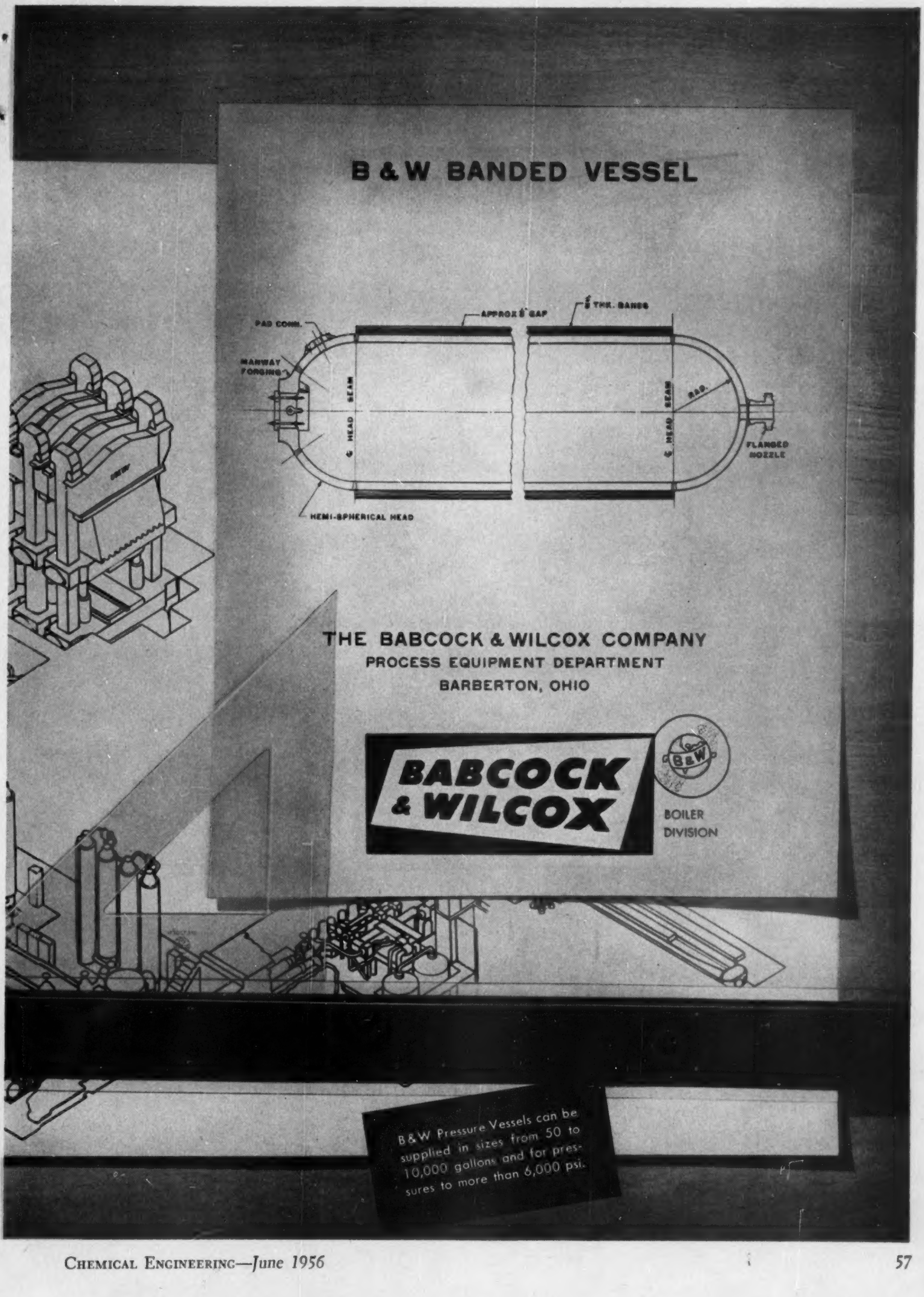
1–402

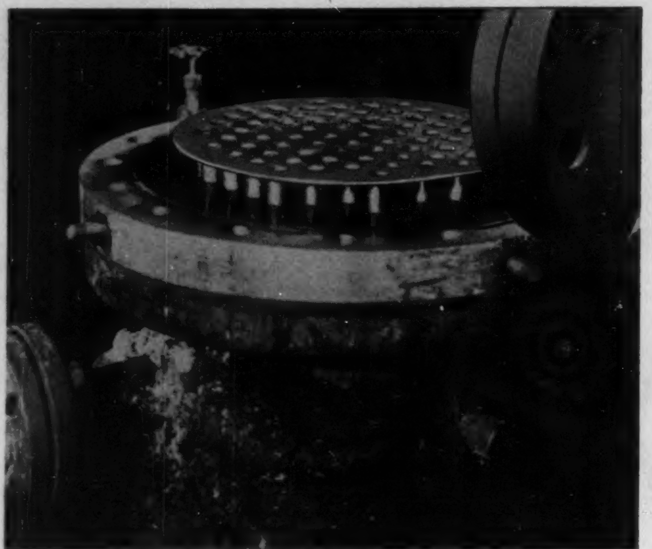
11 Broadway, New York 4, N. Y.

COMPRESSORS • GAS AND DIESEL ENGINES • ROCK DRILLS • PUMPS • TURBO-BLOWERS • AIR AND ELECTRIC TOOLS

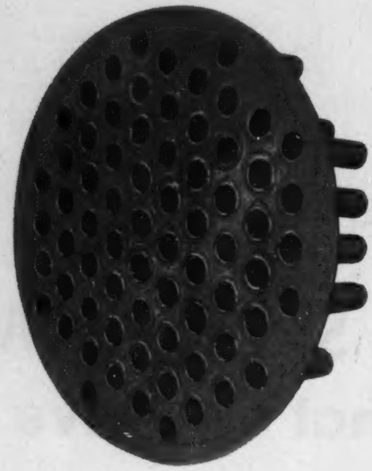


Layout of Installation built by Loewy-Hydropress for USAF Heavy Press Program


B & W BANDED VESSEL
PAD CONN.
MANWAY FORGING
HEAD SEAM
FLANGED NOZZLE
HEMI-SPHERICAL HEAD
THE BABCOCK & WILCOX COMPANY
PROCESS EQUIPMENT DEPARTMENT
BARBERTON, OHIO
BABCOCK & WILCOX
B&W
BOILER DIVISION
B&W Pressure Vessels can be supplied in sizes from 50 to 10,000 gallons and for pressures to more than 6,000 psi.



'Top-hat' of REM-CRU titanium in service on condenser at E. I. duPont de Nemours, Inc.



Closeup of titanium 'top-hat'.

how **TITANIUM** 'top-hat' thwarts corrosion damage to DuPont condenser...

Problem: DuPont chemical engineers faced a particularly vexing problem in the frequent failure of a stainless steel condenser handling 60% nitric acid at 480F and 300 psi. Every five months or so, it became so badly corroded that replacement was necessary. Unit costs and downtime were serious.

Solution: Since failures always occurred at the condenser top, DuPont engineers decided to try protecting that area with a 'top-hat' insert of REM-CRU titanium. It consists of a titanium disc twelve inches in diameter, to which a cluster of 70 thin wall titanium tubes is welded. Fitting snugly into the top of the stainless steel condenser, the titanium protects the area where trouble started. *And it stopped failures completely.* The 'top-hatted' condenser has been in service for more than 16 months and still shows no sign of corrosion beyond a slight discoloration.

Dollars and Cents Facts About Titanium: It's true that titanium sheet and tubing cost more than stainless steel. But titanium's light weight (40% lighter than steel), means you must buy fewer pounds of *metal* for a given area. Furthermore, the cost of the metal is only a fraction of the cost of the finished assembly. Substituting titanium for stainless, therefore, increases the cost of a finished reactor, autoclave, valve or other piece of chemical equipment by only two or three times. Where titanium extends the service life of parts by such a factor, or eliminates costly maintenance and downtime, it's the obvious choice over cheaper but less corrosion-resistant metals.

At REM-CRU you can now get *prompt* delivery of this versatile metal in a wide variety of sizes, shapes and grades — including new high-strength, weldable alloys. REM-CRU engineers will be glad to help with selection, application or fabrication problems.

To keep abreast of the latest developments on this vital metal, write to Dept. C-6 for the Rem-Cru Review — a free periodical presenting the latest technical data on titanium alloys.

REM-CRU TITANIUM

REM-CRU TITANIUM, INC., MIDLAND, PENNSYLVANIA

Now — continuous, accurate control of electrically heated equipment

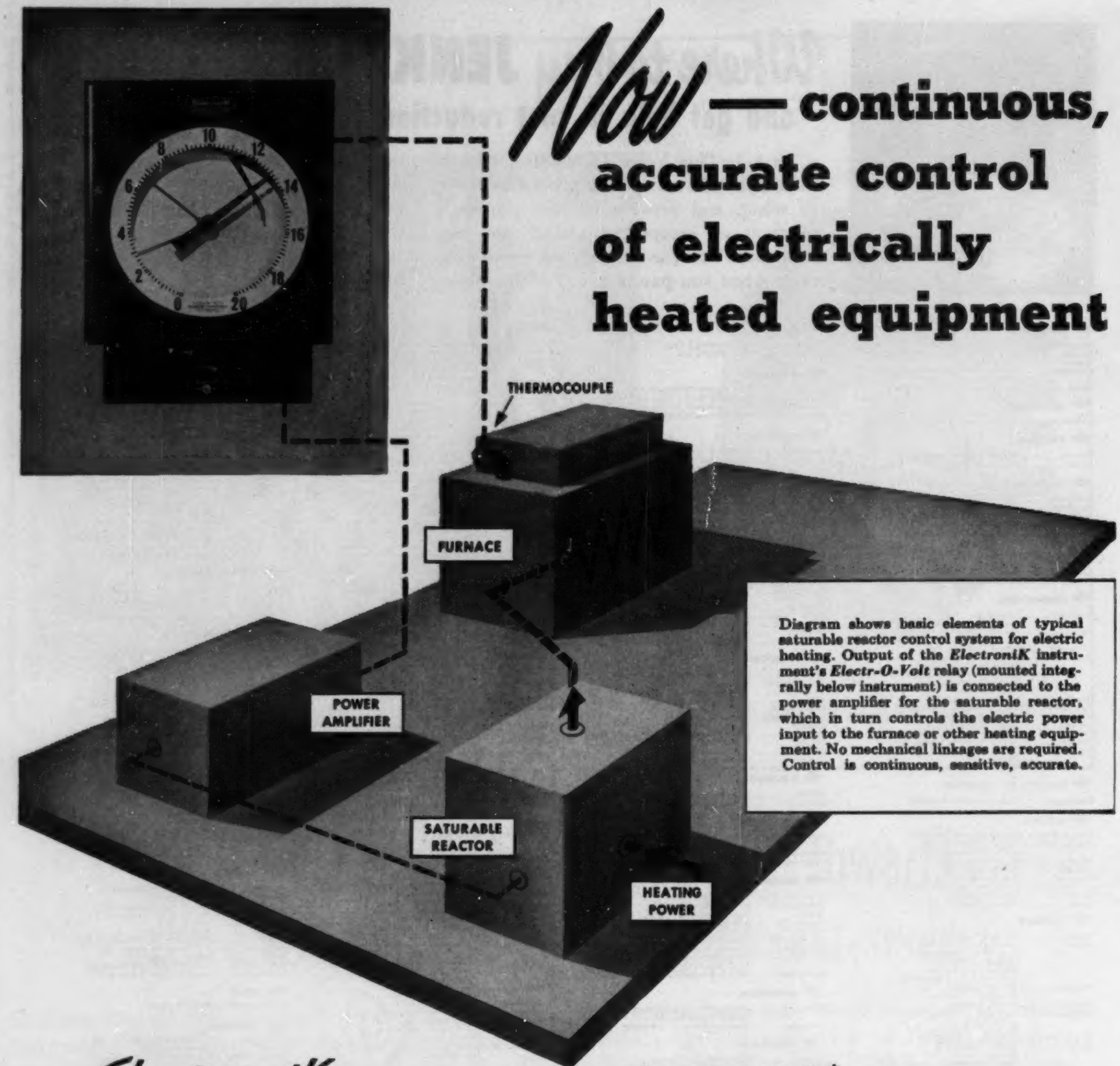


Diagram shows basic elements of typical saturable reactor control system for electric heating. Output of the *ElectroniK* instrument's *Electr-O-Volt* relay (mounted integrally below instrument) is connected to the power amplifier for the saturable reactor, which in turn controls the electric power input to the furnace or other heating equipment. No mechanical linkages are required. Control is continuous, sensitive, accurate.

ElectroniK instrumentation with Electr-O-Volt* *relay provides continuous throttling in saturable reactor control systems*

You can now regulate temperatures of electrically heated furnaces, ovens, and similar processing equipment within exceptionally close tolerances, by using an advanced *ElectroniK* control system in conjunction with saturable reactors. This type of control eliminates the abrupt surges of power and the expense of contact replacement which are frequently objectionable factors of on-off or pulsed electric control.

Continuous control. The *Electr-O-Volt* relay, actuated by the *ElectroniK* instrument, provides continuously variable control input to the saturable reactor power amplifier. This arrangement gives true proportional-plus-reset control action, which adjusts heat input to compensate for size of load, ambient temperature and other variations in heat demand.

Completely electronic. The system has no mechanical linkages, contactors, or other complex moving parts. Its high speed and sensitivity give the precise control required by modern processes.

Broad range of use. *ElectroniK* control for saturable reactors is applicable to high-temperature heat-treating furnaces, reaction vessels and other electrically heated equipment. It makes possible smooth, finely-adjusted regulation of electric power at high efficiency.

For a discussion of how you can use this control, call your local Honeywell sales engineer . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division,* Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

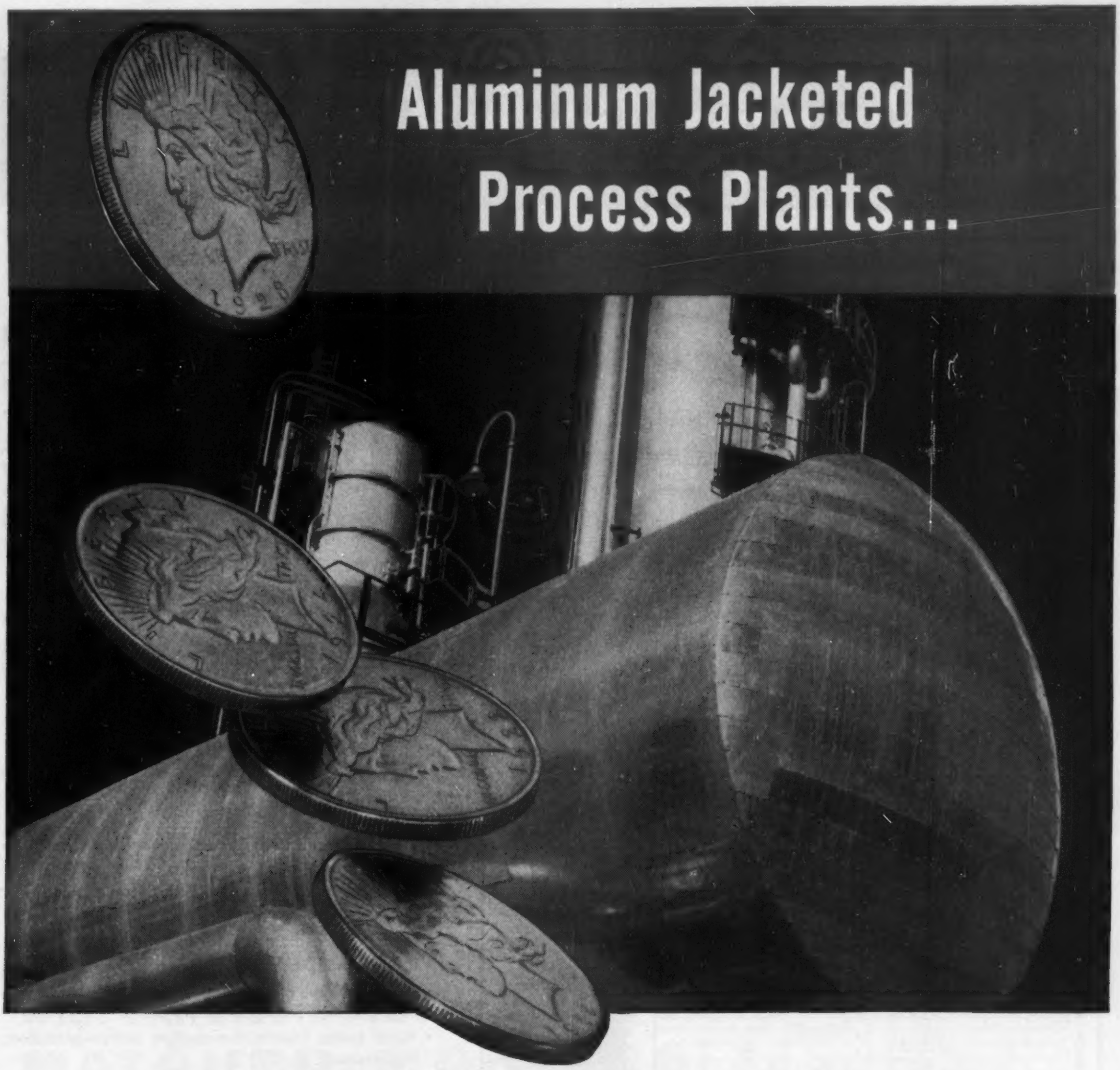
*Trademark

● **REFERENCE DATA:**
Write for Catalog 1531, "ElectroniK Controllers,"
and for new specifications S152-2-"Electronik Instruments with Electr-O-Vane Proportional Control"

H HONEYWELL

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS

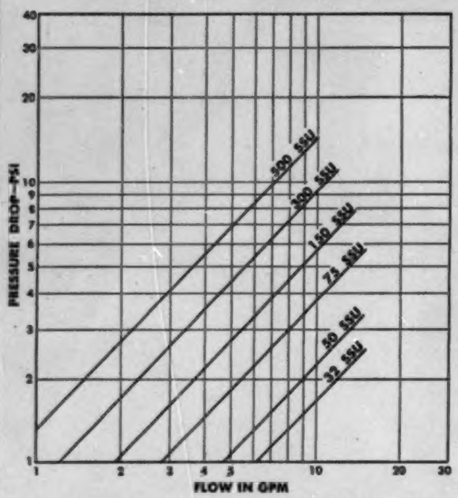
First in Controls

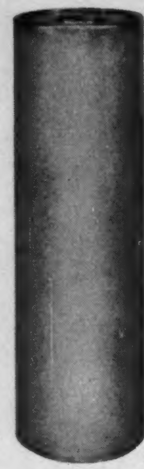

Aluminum Jacketed
Process Plants...

DESIGN AND APPLICATION NOTES ON

Cuno's new Poro-Klean Filter

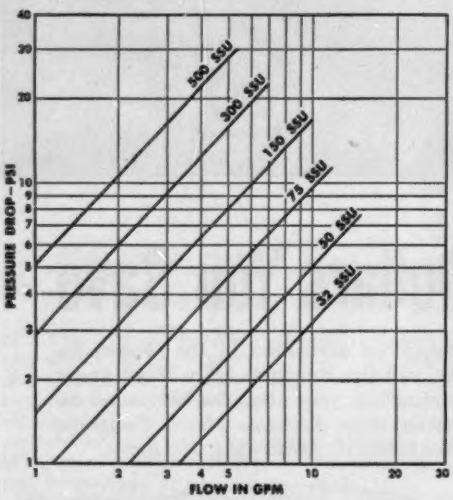
TYPICAL PORO-KLEAN FLOW DATA

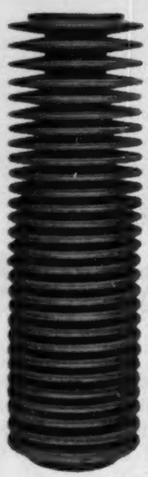




CYLINDRICAL TYPE

FLOW DATA FOR TYPICAL CYLINDRICAL-TYPE, coarse-grade, Poro-Klean filter element, fluid viscosity as parameter. Filtration to 15 microns.





CELL TYPE

FLOW DATA FOR TYPICAL CELL-TYPE, medium-grade, Poro-Klean filter element, fluid viscosity as parameter. Filtration to 5 microns.

Precision 3-to-30 micron filter for high temperature and high pressure

Poro-Klean, Cuno's new porous stainless steel filter material, now offers the chemical, petrochemical, nuclear, and process industries true micronic filtration for temperatures to 900°F and differential pressures to 2000 psi.

Standard in 316 stainless steel, with low carbon content (0.03 to 0.05% max.), Poro-Klean is an ideal filter material for use in applications requiring corrosion resistance, high strength (ultimate tensile strength: 25,000 psi), high resistance to hydraulic shock, or positive freedom from fluid contamination.

Typical Poro-Klean applications, already in use in the chemical and process industries, are listed below. Approximate flow-rate curves for typical cell and cylindrical standard elements are shown at left (for exact data, see your Cuno representative).

TYPICAL PORO-KLEAN APPLICATIONS

TO REMOVE:

- Resin and airborne contamination from demineralized water
- Fixed-bed catalyst fines from petroleum products
- Over-cooked gels from polymers
- Radioactive contamination from light and heavy water
- Fine precoat particles downstream from primary filters
- Contamination and/or catalysts from high-temperature and high-pressure refinery gases
- Metal oxides from molten sodium, sodium-potassium, and bismuth
- Iron oxides from fuels
- Rust from steam
- Foreign matter from pharmaceuticals

TO RECOVER:

- Catalysts from gases and liquids

TO DISPERSE:

- Gases into liquids and other gases

If you have problems like these, let Cuno engineers help you apply Poro-Klean to their solution. See your Cuno representative, or write Cuno Engineering Corporation, 31-6 South Vine Street, Meriden, Conn. 5.20

CUNO **ENGINEERED FILTRATION**

Removes More Sizes of Solids From More Kinds of Fluids

AUTO-KLEAN (edge type) · MICRO-KLEAN (fibre cartridge) · FLO-KLEAN (wire-wound) · PORO-KLEAN (porous stainless steel)

Nicholson *steam trap* capacity *gives you...*

faster, more effective condensate removal

Write, today, for your copy of new Bulletin 10-55—for detailed information.

Nicholson capacity is greater than that of any other trap of the same size. And, greater capacity—right across the board—means the Nicholson trap discharges condensate and air from chemical process steam lines and equipment *faster*, more *effectively*.

- **powerful valve action—big husky bellows.**
- **positive shut-off—finely ground valve and seat.**
- **high capacity—effective use of large orifice.**
- **each unit service tested—with steam.**

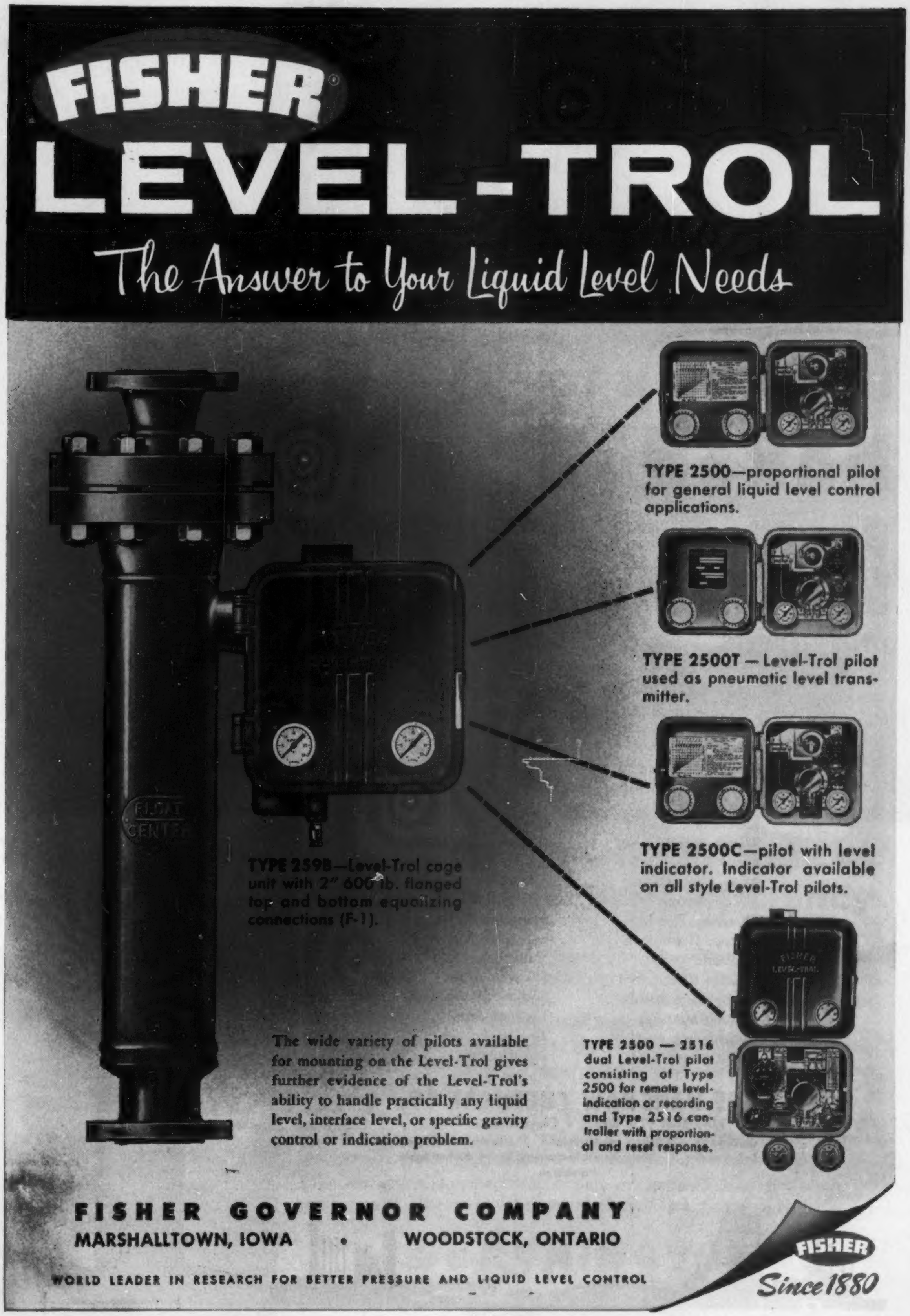
When less than the best won't do, specify Nicholson.

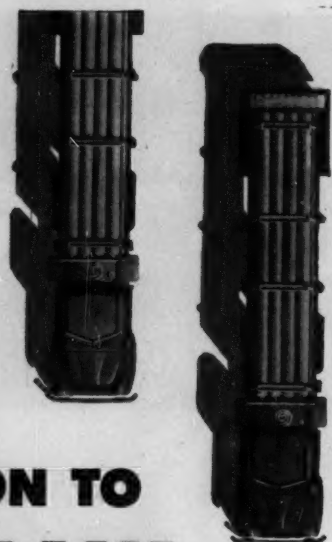
NICHOLSON

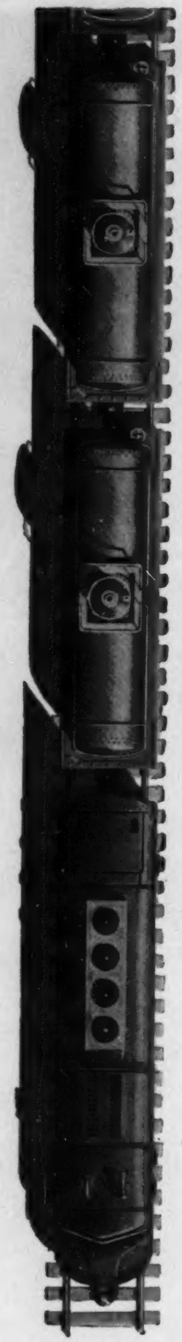
W. H. NICHOLSON and Company

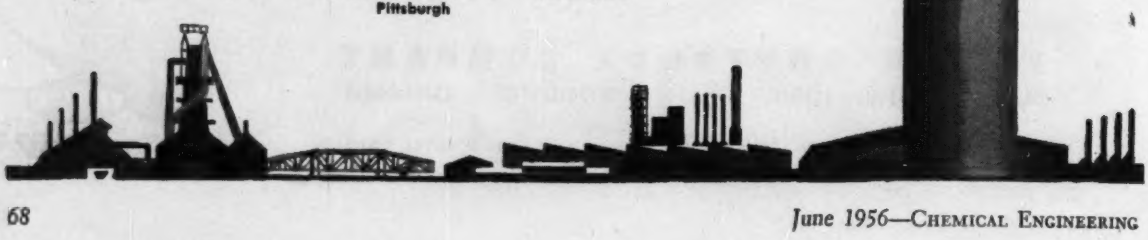
TRAPS • VALVES • FLOATS • METAL PARTITIONS
LAUNDRY, DRY CLEANING AND PRESSING MACHINERY

14 OREGON STREET, WILKES-BARRE, PA. • SALES AND ENGINEERING OFFICES IN 98 PRINCIPAL CITIES

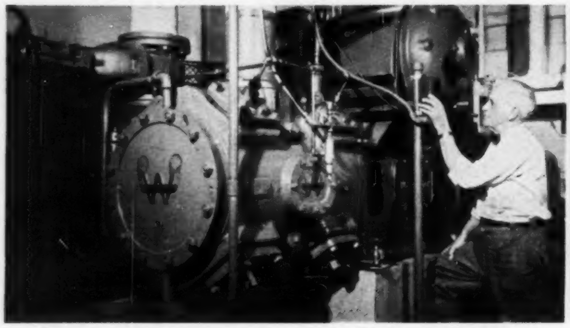

FISHER
LEVEL-TROL
The Answer to Your Liquid Level Needs
TYPE 2500—proportional pilot for general liquid level control applications.
TYPE 2500T — Level-Trol pilot used as pneumatic level transmitter.
TYPE 2500C—pilot with level indicator. Indicator available on all style Level-Trol pilots.
TYPE 259B—Level-Trol cage unit with 2" 600 lb. flanged top and bottom equalizing connections (F-1).
FLOAT CENTER
The wide variety of pilots available for mounting on the Level-Trol gives further evidence of the Level-Trol's ability to handle practically any liquid level, interface level, or specific gravity control or indication problem.
TYPE 2500 — 2516 dual Level-Trol pilot consisting of Type 2500 for remote level-indication or recording and Type 2516 controller with proportional and reset response.
FISHER GOVERNOR COMPANY
MARSHALLTOWN, IOWA • WOODSTOCK, ONTARIO
WORLD LEADER IN RESEARCH FOR BETTER PRESSURE AND LIQUID LEVEL CONTROL
FISHER
Since 1880



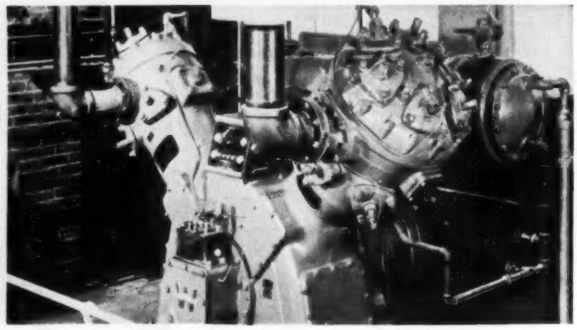




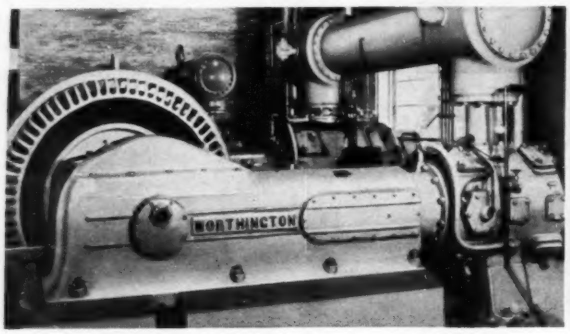
No compromising machine selection with this complete compressor line



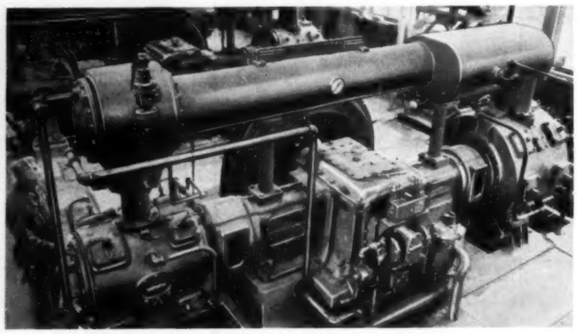
Single-stage compressor, type HB. For economical, continuous supply of air in smaller quantities. Sizes range from 10 to 125 hp. (Bulletin L-640-B1C)



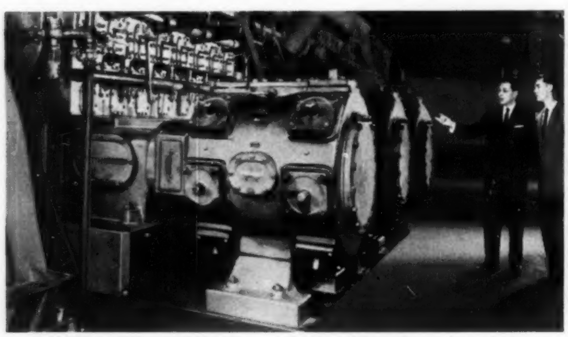
Two-stage angle compressor, type YC. Most compact unit for its capacity. Available up to 250 hp, and in larger sizes in similar type DYC. (Bulletin L-676-B1A)



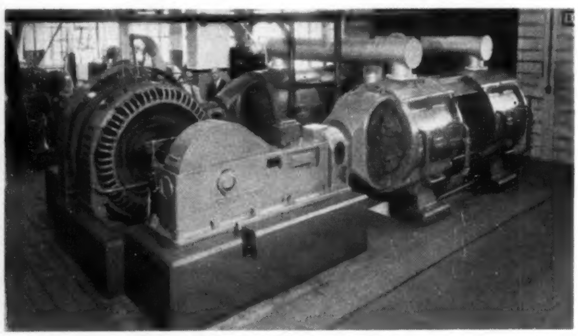
Horizontal duplex compressor, type DC-2. A two-stage compressor designed for heavy-duty service. From 250 to 3,000 hp. (Bulletin L-675-B1B)



Balanced opposed compressor, type BDC. Versatile—ideal for either multiple or single-service applications. Sizes from 300 to 10,000 hp. (Bulletin L-679-B1)



SUTC gas-engine compressor. Most complete process flow flexibility with 2-cycle compactness. Available in ratings from 750 to 2,500 hp. (Bulletin S-550-B23D)



Vacuum pump. This Worthington "compressor in reverse" provides pressures as low as .25 psia. Available in sizes from 10 through 2,500 hp. (Bulletin L-600-B9-4)

A compressor and drive for your every compression job is available in the standard Worthington line. Sizes range up to 10,000 hp, air and gas pressures to 35,000 psi. For more information about any of these Worthington compressors, write to Section K64, Worthington Corporation, Harrison, N. J. In Canada: Worthington (Canada) 1955, Ltd., Toronto, Ont.

K.6.4

WORTHINGTON

DU PONT

Better Things for Better Living ... through Chemistry

CHEMICAL ENGINEERING NEWS

PROPERTY AND APPLICATION DATA
ON THESE VERSATILE ENGINEERING MATERIALS:
"ZYTEL," "ALATHON," "TEFLON," "LUCITE."

Chemically inert TEFLON® simplifies design in new mechanical seal

...offers economical service on pumps handling corrosives

TEFLON® can now be cemented with conventional adhesives

A new process provides a cementable surface on shapes fabricated from "Teflon" tetrafluoroethylene resin. Chemically inert, "Teflon" normally refuses to stick to anything. After treatment, however, "Teflon" may be bonded with conventional adhesives to a wide range of other materials as well as to itself.

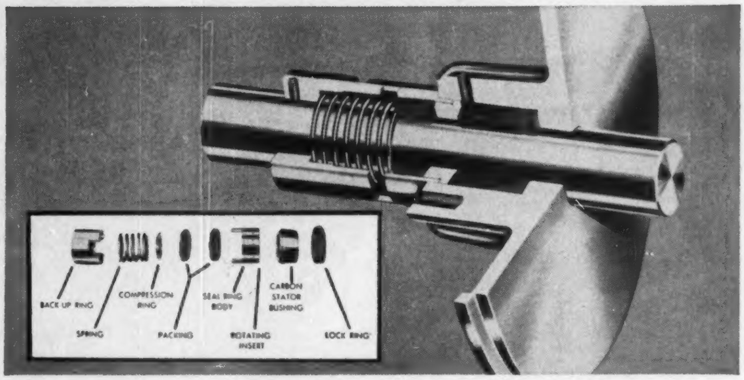
Fittings of ZYTEL® provide leak-proof connections on tubing

Compression-type "Jaco" fittings of molded "Zytel" nylon resin simplify installation and disassembly. In this new design, the ferrule necessary for a leak-proof seal is molded as an integral part of the nut. The resiliency of "Zytel" enabled this fitting to withstand a test of more than 25,000,000 oscillations. "Zytel" forms a non-corrosive connection, impervious to most acids and alkalies, and capable of withstanding pressures to 500 p.s.i. Its service temperature ranges from –70° to 295° F. Fittings are molded by Jaco Manufacturing Company, Cleveland, Ohio.

This versatile Du Pont engineering material is a time and cost saver in many applications where lightness in weight, heat resistance, corrosion resistance and strength in thin sections are essential. Investigate this product further by mailing the coupon below.

NEED MORE INFORMATION?

Clip the coupon for additional data on the properties and applications of these Du Pont engineering materials.



Exploded and cross-sectional view of new mechanical seal, with parts of "Teflon" shown in red. Seal can be rapidly interchanged with packing.

Latest design in mechanical seals features complete and rapid interchangeability with packing. Developed by Chemical Power and Products, Inc., New York City, this new seal can be made to fit any stuffing box, requiring no alterations or special clamps. It offers economy by eliminating product loss and minimizing installation and downtime.

"Teflon" tetrafluoroethylene resin plays the feature role in the sealing of corrosive liquids and slurries. It is used as a shaft packing in the form of a male and female cup, and providing maximum flexibility with minimum spring pressure as a wedge lock in the bottom of the seal to prevent leakage and stop rotation of the stator. The self-aligning wedge lock of "Teflon" slips easily in place, and the time and expense involved in installing a clamp to hold the stator are eliminated.

"Teflon" is selected in sealing applications because of its superior physical and chemical properties. "Teflon" is chemically inert—alkali metals and fluorine, under unusual conditions, are the only ordinary industrial chemicals which will attack it. This unique engineering material will operate at service temperatures ranging from –450° to 500° F. "Teflon" is nonflammable, and has zero water absorption by ASTM test. It has low-temperature toughness and an exceedingly low coefficient of friction.

For handling corrosive chemicals, "Teflon" offers unexcelled service for such items as pump impellers, expansion-joint bellows, filters, tubings, and gaskets and packings. If you have a problem involving extreme heat and corrosion, investigate the use of "Teflon." For property data that will help you analyze your problems in terms of this unique material, clip and mail the coupon below.

E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department
Room 256, Du Pont Building, Wilmington 98, Delaware
In Canada: Du Pont Company of Canada Limited, P.O. Box 660, Montreal, Quebec

Please send me complete property and application data on Du Pont "Teflon" ☐ and "Zytel" ☐.

I am interested in evaluating these materials for

____

____

Name____________________

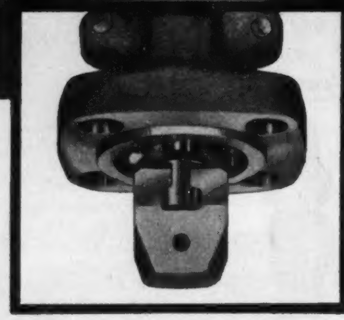
Firm Name____________________

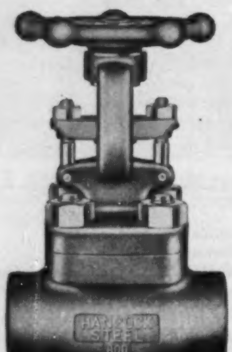
Position____________________

Type of Business____________________

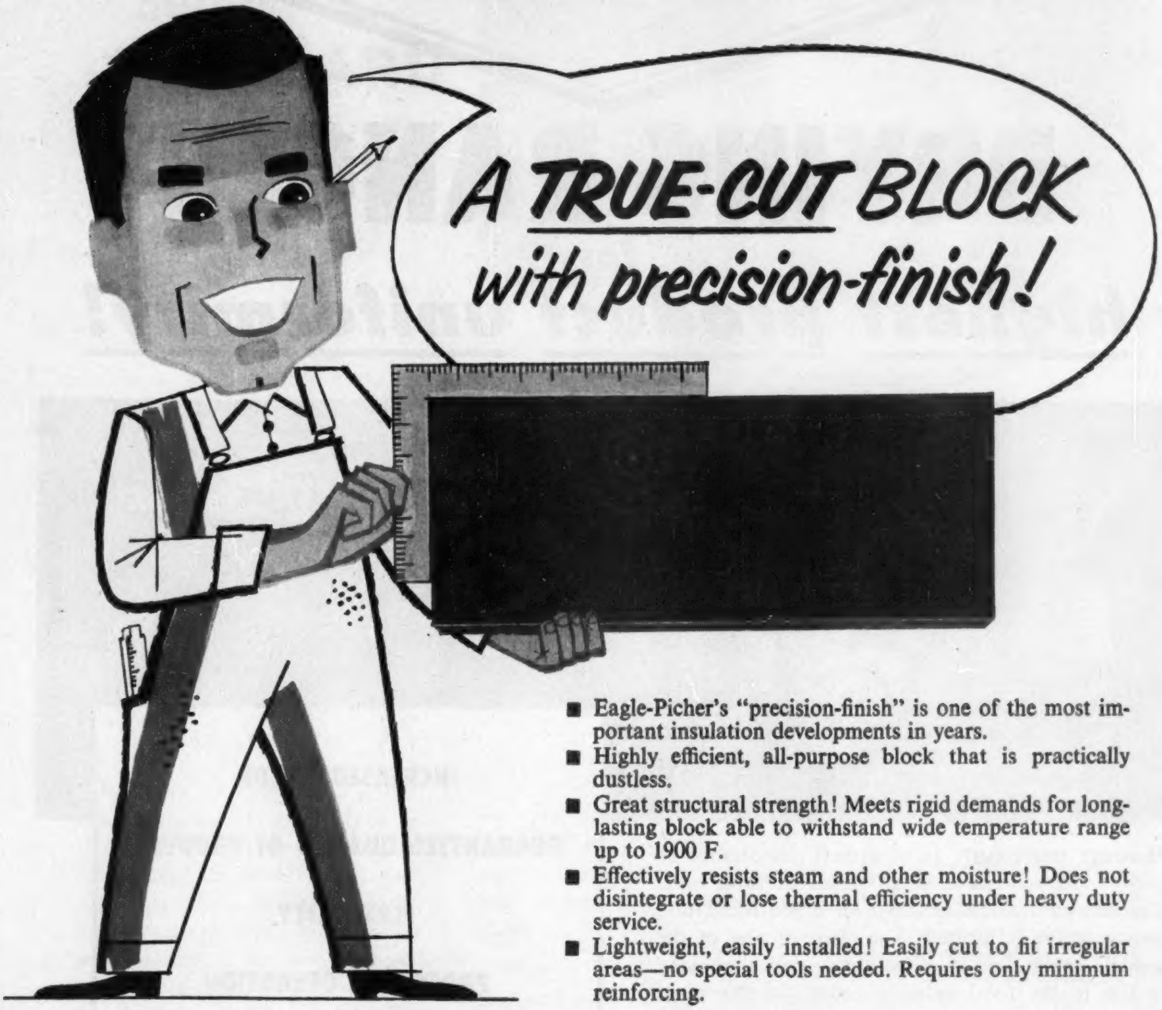
Street Address____________________

City____________ State____________




HANCOCK
STEEL
800

EAGLE-PICHER
PV SUPERTEMP
BLOCK INSULATION



- Eagle-Picher's "precision-finish" is one of the most important insulation developments in years.
- Highly efficient, all-purpose block that is practically dustless.
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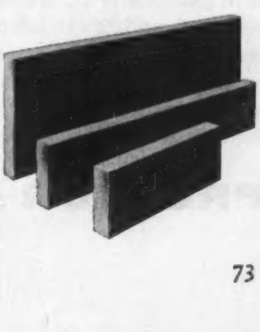

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MIXING GASES WITH LIQUIDS • AERATING • GASIFYING • OPERATED IN ANY TYPE OPEN OR SEALED VESSEL
Struthers Wells
RADIAL PROPELLER Agitator
Agitator drives range in speed from 10 RPM to 500 RPM; from fractional to 50 h.p. with stuffing boxes or mechanical seals for pressures up to 500 pounds or more.
Quick opening manhole for inspection or filling.
Semi-flexible coupling protects shaft bearings from bending movements.
Vertical baffles supported by a nozzle in the top head eliminating pockets in which materials may accumulate and providing easy outside adjustment.
Radial propeller agitator is simple, efficient and self-cleaning.
Struthers Wells flush bottom valves are available in several sizes and materials.
Removable bottom guide bearing simplifies maintenance.
The peripheral angle of the blades can be made to meet any requirement.
The illustration at left shows the Struthers Wells Radial Propeller Agitator mounted in a heavy-duty stainless steel mixer. Radial Propeller Agitators are available in all commercial sizes and materials, and can be specifically designed for any practical liquid agitating requirement.
Write for Bulletin 58-W
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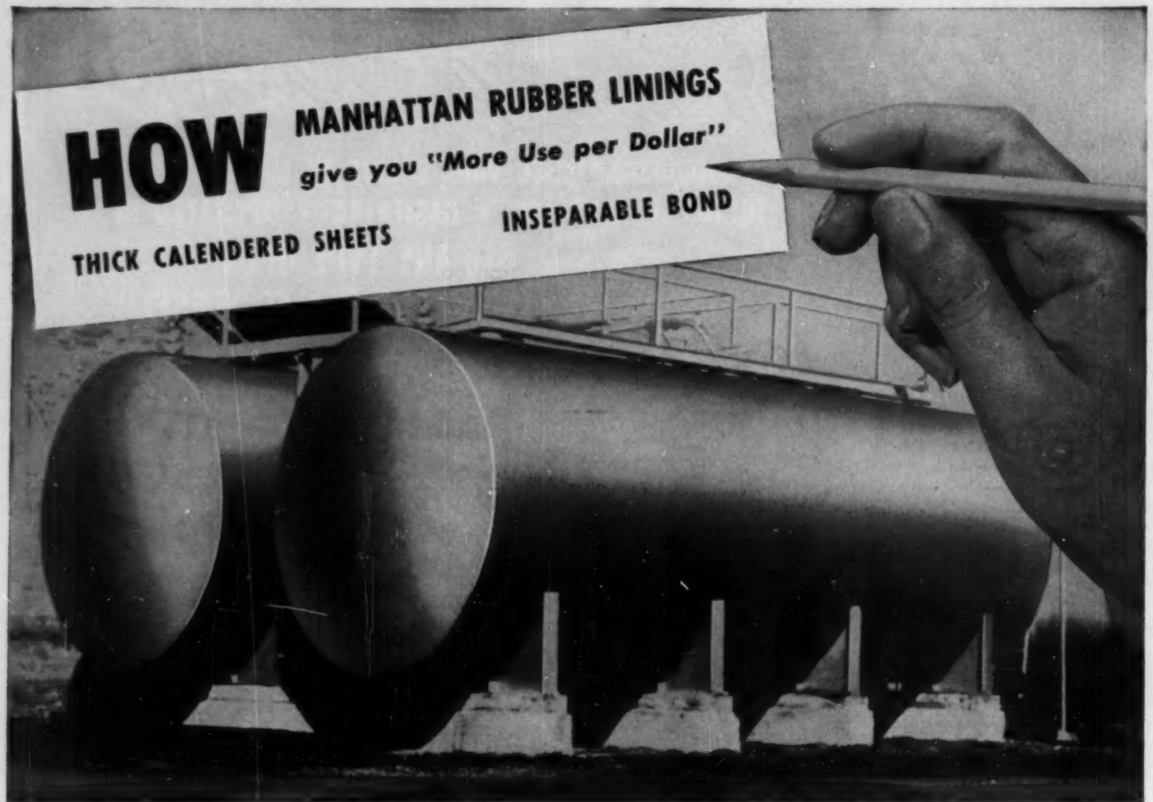
Offices in Principal Cities



(Courtesy A. H. Mathieu & Company)

MANHATTAN Rubber Linings Assure Permanent Protection against Corrosion, Contamination, Abrasion

You get *real* protection . . . *permanent,* positive protection against losses due to corrosion, contamination and abrasion with Manhattan Rubber Linings. That's because Manhattan engineers have developed a special method of bonding rubber to metal so securely that actual on-the-job tests have proved it can't be separated! Manhattan Rubber Linings are made from thick, calendered sheets of natural or synthetic rubber, whichever is best suited, for maximum durability. They expand and contract with the metal under temperature changes—won't harden or crack. Their resistance to most acids, caustics and alkalis is as permanent as is possible to make them.

To make certain your Manhattan Rubber Lining is flawless and permanent, every Manhattan Lined Tank is tested under high voltage to detect any possible imperfections. More than 60 years of research and manufacturing "know-how" at Manhattan have led to the development of many high quality linings . . . each designed for specific application. Regardless of the size or shape of your processing equipment, Manhattan has the facilities to handle your job . . . the most modern and complete available today. Equipment too large to be shipped can be field lined and vulcanized by skilled Manhattan crews. For rubber lining that lasts longer, contact an R/M representative at the Manhattan Rubber Lining plant nearest you.

RM 621

RUBBER LINING PLANTS AT PASSAIC, N. J. and NORTH CHARLESTON, S. C.
MANHATTAN RUBBER DIVISION—PASSAIC, NEW JERSEY

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Other R/M products include: Industrial Rubber • Fan Belts • Radiator Hose • Brake Linings • Brake Blocks • Clutch Facings
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LAYNE
Rx Making sick wells . . . WELL!
First comes diagnosis. Before the cure the trouble must be known so that proper treatment may be prescribed.
Trained Layne research men, with the help of the latest and best in scientific equipment, find the trouble . . . determine the corrective measures . . . and experts go to work.
Successful? . . . One smaller Southern city saved the cost of a new well at a nominal cost. And that's just one success in a long line of sick wells that have been made well by Layne.
The nearest Layne associate company will be glad to discuss such problems with you—without obligation. It's another Layne service that proves it's always wise first to "ASK THE MAN FROM LAYNE" on any phase of water development or maintenance.
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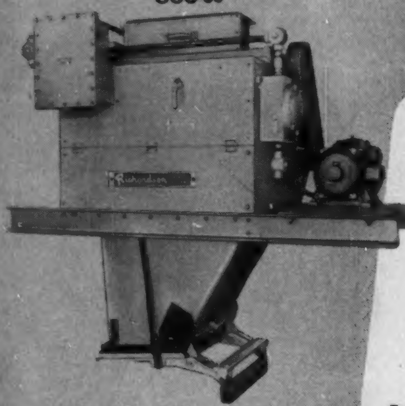
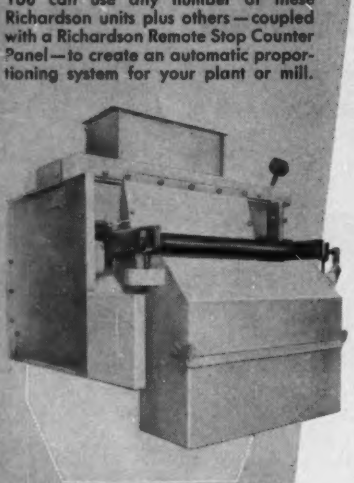
proportioning costs up?

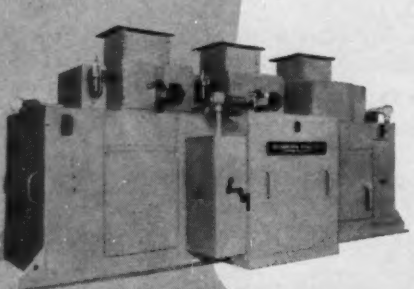
GGG-38



You can use any number of these Richardson units plus others—coupled with a Richardson Remote Stop Counter Panel—to create an automatic proportioning system for your plant or mill.



HHH-38



E-50 Triplex

Cut 'em down with the simplest, most dependable, accurate and inexpensive system you can own!

Like to switch to automatic proportioning?...or saddled with a complex, inefficient or outmoded system that isn't giving you that *extra* increment of speed and accuracy that you must have to show a real profit?

Here's the answer. By combining standard Richardson Scale batch weighing units like those shown here with a Richardson Remote Stop Counter Panel, you get virtually continuous-stream delivery, with the kind of accuracy you couldn't hope for with a continuous weighing scale. What's more, with a system made of simple, easy-to-maintain Richardson units—interlocked for simultaneous delivery—you get an inexpensive system that's tailored to fit the exact needs of your plant or mill. In many cases, depending on materials, complexity of the blend and other factors—a *simplified* Richardson Automatic Proportioning System can do the job of a much more expensive, much more complex fully-automated system.

WRITE TODAY for further information about cost-saving, space-saving, labor-saving Richardson Proportioning Systems. Ask Richardson for a recommendation to solve *your* particular problem. RICHARDSON SCALE CO., Clifton, N. J.

Richardson

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RICHARDSON SCALE COMPANY, Clifton, New Jersey

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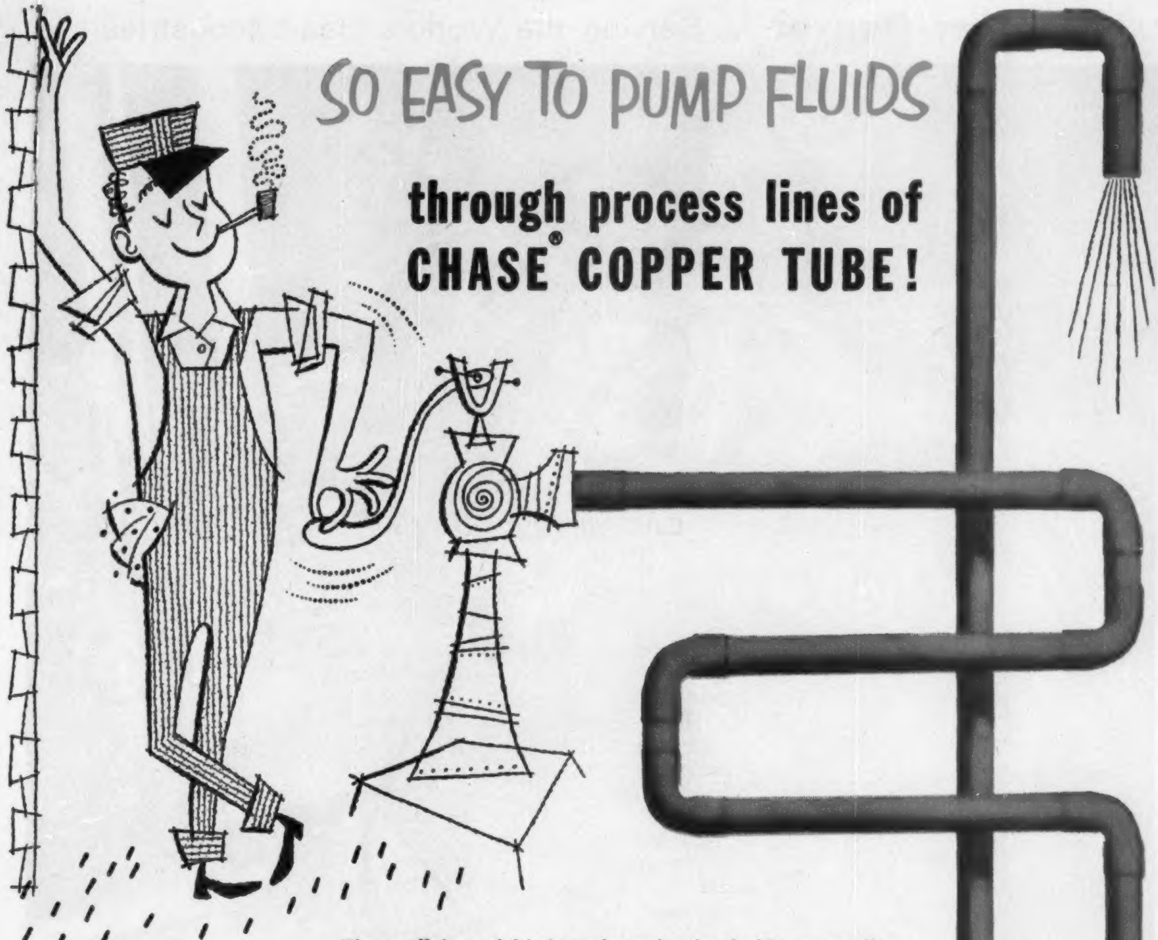
Richardson Scales S.A., 1-3 Rue de Chantepoulet, Geneva, Switzerland
Richardson Scale Co., Ltd., 40-42 George Street, Nottingham, England

Remote Stop Counter Panel

2398



The coefficient of friction takes a beating inside process lines of Chase copper tube! The inside of this clean tube is satin-smooth, so even the heaviest industrial fluids flow more easily. That means pumps need not strain to keep fluids moving—*pumping costs stay low!*

Tests actually show that coefficients of flow remain essentially unchanged with *time* or *quantity of liquid* pumped through Chase copper tube. This is not true of other metals where clogging *rapidly increases* resistance to flow. What's more, Chase copper tube is corrosion-resistant—can't clog with *rust!*

Your Chase wholesaler or the Chase warehouse near you can give you full information on Chase copper tube. *Call them!*

Chase®

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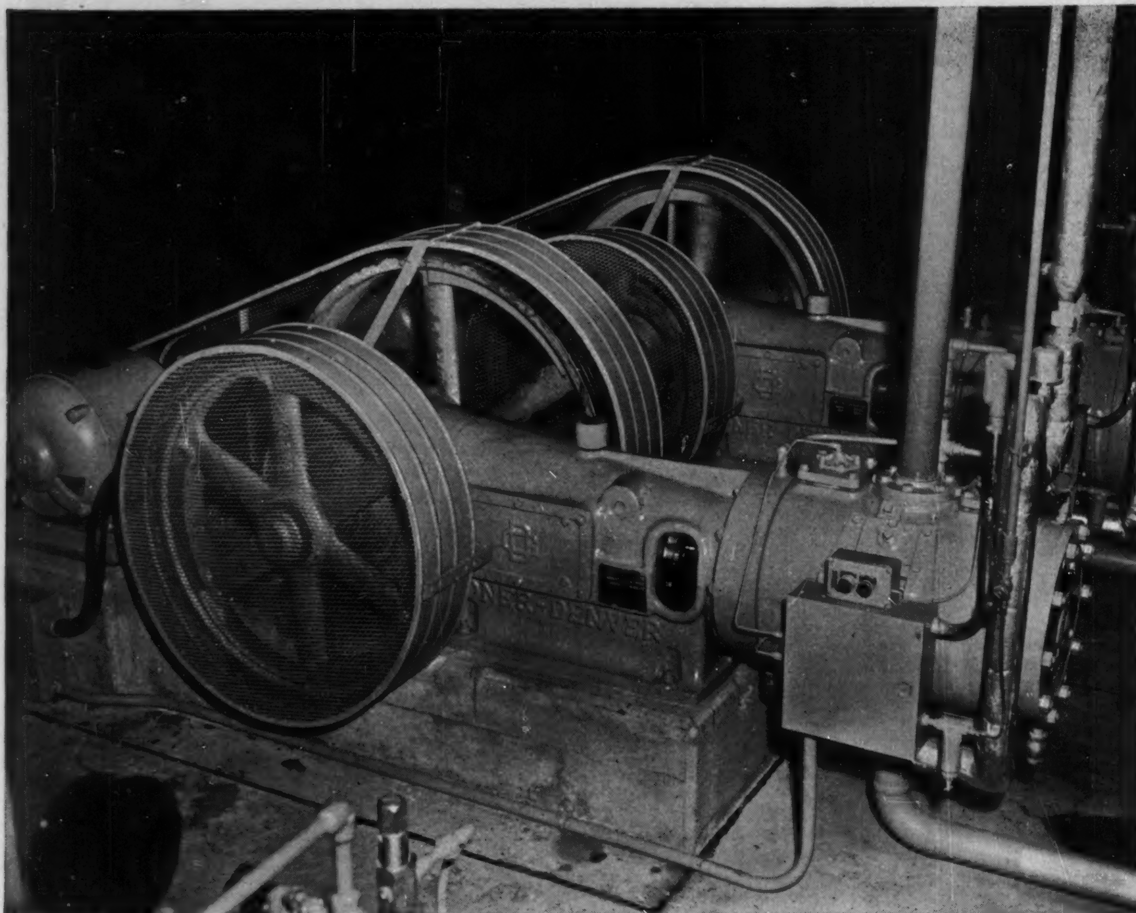
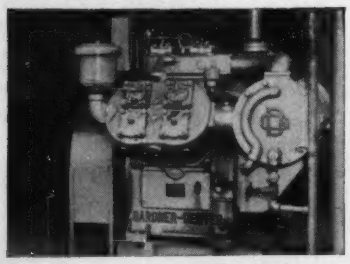


Built for the 168-hour week . . .
Gardner-Denver RX Compressors

That's *continuous* service . . . and it goes on year after year in all sorts of plants where Gardner-Denver RX's occupy the compressor room. Bearings, valves and other moving parts are engineered to keep on the go . . . seldom require more than brief inspection halts. Bulletin HAC-40 gives details on RX models from 89 to 1292 cfm, for pressures from 15 to 150 psi. Write today.



Another popular industrial compressor . . . the compact, efficient Gardner-Denver WB. 142 to 1150 cfm.

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You get more than a conveying system at

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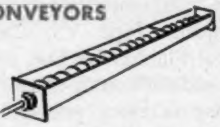
You get many *plus* values when you deal with Sprout-Waldron. In conveying systems, you get a wide choice of types, styles, and sizes. And all can be tailored to fit your needs by Sprout-Waldron's unique methods of "adaptioneering."

You also get reliable guidance on installations and applications from our engineering representatives and engineering staff. Their recommendations are based on long experience and backed by case history files of successful processing applications and laboratory tests.

DAVE SMYTH

A member of Sprout-Waldron's Quarter Century Club, Dave Smyth has been serving the needs of his customers for 27 years. And before joining Sprout-Waldron, he served the processing industries through a mill supply house. Industrial America's biggest names have profited by Dave's assistance in solving problems. With such men to help you, you're bound to buy *right* at Sprout-Waldron.

SCREW CONVEYORS

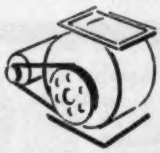


Sprout-Waldron vertical and horizontal screw conveyors are extremely low in maintenance and moderate in power requirements. Available in conventional helicoid, continuous sectional, and sectional types. Ask for literature.

BUCKET ELEVATORS

Sprout-Waldron offers bucket elevators in bucket sizes from 3" x 3" to 30" x 16"... wood, stainless steel, carbon steel, and aluminum . . . chain or belt, high speed or conventional. Write for full facts.

FEEDERS



You'll find the simplest, sturdiest, and easiest-to-maintain feeders at Sprout-Waldron. Ours is the most extensive line to be found anywhere. And the many years of experience we have gained through pioneering in this specialized field assures you of the greatest possible savings. Get details.

SPROUT SW WALDRON

SPROUT-WALDRON

PNEU-VAC

pays 11 ways

1. **Increased production—greater safety.**
2. **99.96% material recovery.**
3. **Lower maintenance costs.**
4. **No product intercontamination.**
5. **No fan wear.**
6. **No infestation.**
7. **No handling losses.**
8. **Elimination of exterior dust.**
9. **Improved working conditions.**
10. **Small space requirements.**
11. **Horizontal, vertical, around corners.**

In this modern, negative-pressure or draw-through system, the fan is located on the opposite side of the collector from the material conveying line. Material does not pass through the fan. Mechanical friction and exterior dusting are eliminated. The unit is self-cleaning. It can cool, heat, aerate, or dry. Materials can be routed anywhere you can run a pipe. There is a minimum of moving parts.

Thorough experience in application and design is essential to getting best results from any pneumatic system. Sprout-Waldron is one of the country's foremost designers and builders of pneumatic systems, and has been manufacturing Pneu-Vacs for more than 9 years. Be sure to compare Pneu-Vac with all others before installing any pneumatic conveying equipment. Write for details.

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Manufacturing Engineers Since 1866

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Equipment for SIZE REDUCTION, MIXING & BLENDING, PELLETING & CUBING, BULK MATERIALS HANDLING, PRODUCT CLASSIFICATION

Facilities for fabricating, machining, custom founding, woodworking, laboratory testing

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There's a WILLIAMS Mill

to do the job...better, faster, at lower cost!

Whatever the material—mineral, vegetable, animal or chemical—you'll find a Williams Mill to crush, grind, shred or pulp it to exactly meet your most critical specifications. Of equal importance, and regardless of the size of the job, there's a size and type that will probably do it in one operation entirely without the need for additional or secondary equipment!

You get more for your investment too, when you choose a Williams! You'll find it more carefully designed, more ruggedly built, for year-after-year service. You'll find it offers the most in low-cost operation, in minimum maintenance, and in features that mean continuously stepped-up production. It will pay you to get *ALL* the facts!

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WILLIAMS EQUIPMENT INCLUDES:

HEAVY DUTY HAMMER MILLS, all sizes... ROLLER and IMPACT MILLS with Air Separation for grinding to 325 mesh or finer... HELIX-SEAL MILLS for fine dustless grinding and non-clog wet grinding... DRYER MILLS... AIR SEPARATORS... VIBRATING SCREENS... COMPLETE "Packaged" PLANTS, ready to install in existing buildings.

WILLIAMS TESTING LABORATORY WILL HELP YOU

Submit your grinding, crushing or shredding problems to Williams for solution—with neither obligation or cost. Simply send enough raw material for a test, and describe the result you want.

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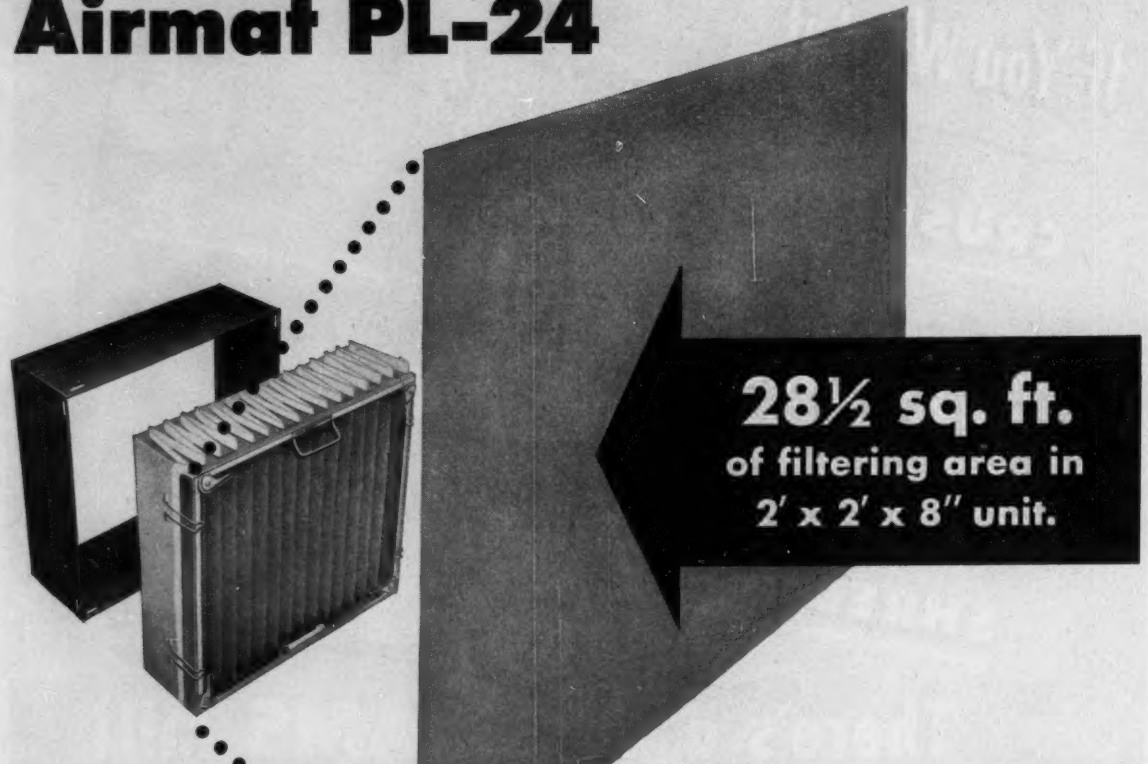
CRUSHERS GRINDERS SHREDDERS

OLDEST AND LARGEST MANUFACTURER OF HAMMER MILLS IN THE WORLD

Airmat PL-24



Inexpensive Airmat media is quickly renewed by means of mechanical loader (as shown) or manual loader.

World's Most Efficient Mechanical Filter for Ventilating and Air Conditioning Service

HIGHEST efficiency plus low initial cost—that's Airmat PL-24, and that's the reason more than a *quarter-of-a-million units* are now supplying business and industry with more than *300 million cfm* of clean air!

The PL-24 packs 28½ square feet of filtering area in a compact 2′ x 2′ x 8″ unit. Deep serrations in media support are at the precise angle for optimum combination of air volume, resistance and uniformity of air distribution. And here's *one* extended-surface dry-type filter with a *positive seal* against air leakage.

PL-24 requires no oil, no water for washing. Low cost Airmat media is quickly replaced when dirty, restoring filter immediately to original high efficiency. Unit construction simplifies installation for any capacity requirements, in straight bank or "V" arrangements. For complete product information, call your nearest AAF representative or write direct for Bulletin 230.

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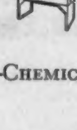
Air Filters and Precipitators



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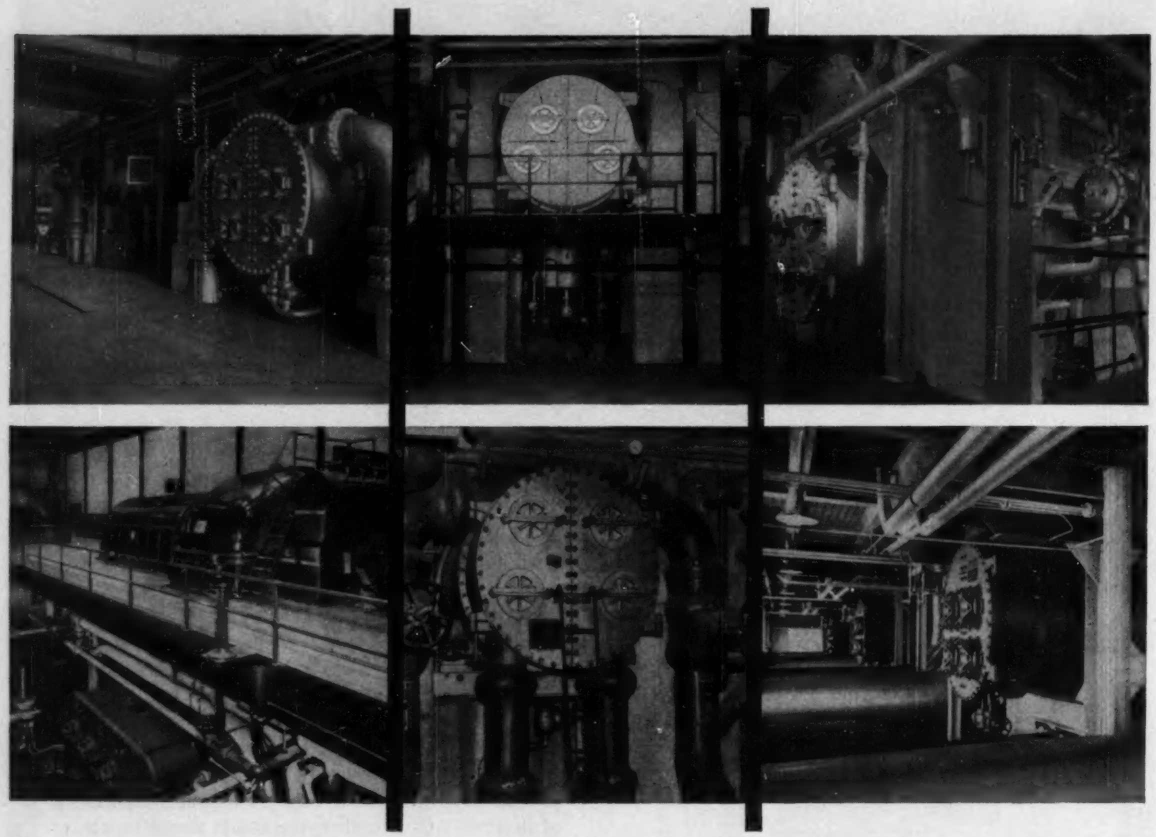

ADSORPTION IS A BASIC CHEMICAL ENGINEERING PROCESS

DARCO *Digest*

DARCO
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CHEMICALS DIVISION, ATLAS POWDER COMPANY, WILMINGTON 99, DELAWARE • Atlas Powder Company, Canada, Ltd., Brantford, Ontario, Canada

Activated Carbon Treatment Improves Quality of Many Products

Treatment with activated carbon is a way to upgrade the quality of many different kinds of products. Primarily a purification process, DARCO treatment adds to consumer acceptance by taking out certain types of things that detract from appeal to the eye, the taste, or the nose.

IMPROVEMENT IN COLOR. In many products, from sugar to sulfa drugs, clear white color is the symbol of purity. Treatment with activated carbon is often the simplest and most economical way to remove color bodies, and thus produce the desired clarity.

IMPROVEMENT IN ODOR. Many of the molecules which cause undesirable odors are readily adsorbed on carbon. Similarly, adsorption often improves taste by elimination of complex molecular impurities that cause unwelcome flavors.

ELIMINATION OF HAZE. Turbidity is usually caused by the precipitation of impurities with limited solubility, which fall out of solution during storage or when subjected to a change in environment. Such impurities are usually easy to remove by adsorption . . . leaving the finished solution clear and attractive.

PREVENTION OF FOAMING. Precursors of undesirable foam, being surface active, are readily removed by adsorption. Where you want to *keep* foam ingredients, but remove others . . . as in treatment of beer to reduce chill haze . . . selection of the right carbon dosage does the trick.

If you've got a product that could be improved by the adsorption process, we'll welcome the opportunity to investigate ways that DARCO can be put to work. Call on us—we're specialists.

Darco is Engineered for Efficient Filtration

Particle size of activated carbon should be small enough to provide speedy access to the adsorptive surface, but large enough to assure adequately fast filtration rates and good filtrate clarity.

In the manufacturing of DARCO activated carbon, thorough precautions are taken to produce the correct particle size. The grinding operation is controlled to give the most effective size of particles and distribution of larger and smaller sizes to provide optimum overall performance. Substantially 100% of DARCO particles pass a 100-mesh sieve, and about 70% pass a 325-mesh sieve.

The result: peak flow of filtrate consistent with efficient adsorption.

IMAGINEERING *with activated carbon*

If you've been used to thinking about adsorption by activated carbon solely as a way to remove impurities from solution, you may be overlooking some interesting possibilities.

Let's go back to fundamentals for a moment. Adsorption, by definition, occurs when there is a greater concentration of solute at a liquid-solid interface than there is in the main body of a solution. Adsorption, in other words, can be considered a method of concentration.

When you have an adsorbable ingredient in solution, consider concentrating the material on the huge adsorptive surface of activated carbon. This technique is standard practice in antibiotic research. One of the final steps in isolating various mold-derived medicinals is adsorption on activated carbon, then elution of the concentrate from the carbon. Often this trick works when there is no other practical means of concentration.

One fly in the ointment—there's no rational way of choosing the elution medium. It's strictly a trial-and-error proposition. Usually two-component systems work best, such as pyridine-water, water-acetone, water saturated with amyl acetate, or acidulated methanol. Our advice: try it and see. You may get results on problems that have defied other methods.

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Just look at them . . . inside as well as out. You'll find that Chapman Motor Units are not only rugged in construction, *they're simple in design.* In fact, a Chapman Motor Unit has approximately *half as many parts* as any other unit.

This simplicity means better, easier operation and lower maintenance costs. It means longer life with fewer repairs.

With Chapman Motor Units your valves seat tight . . . but never too tight. Micrometer adjustment on limit switch insures exact tightness presetting. Drift is eliminated. Lash is slashed. Complete operation by low speed motors is always smooth, accurate and trouble free.

Use them in any position. Quiet, rugged stubtooth gears require no grease or oil. Use them under the most adverse conditions. They're weatherproof, steamtight, dependable.

Installation is quick and easy. Chapman Motor Units and Floorstands are wired and ready to tie in with your leads. Just hitch them up. You're in business.

Get the whole interesting story in our newest catalog 51. Write for it, your copy, now.

The CHAPMAN VALVE Mfg. Co.
INDIAN ORCHARD, MASS.

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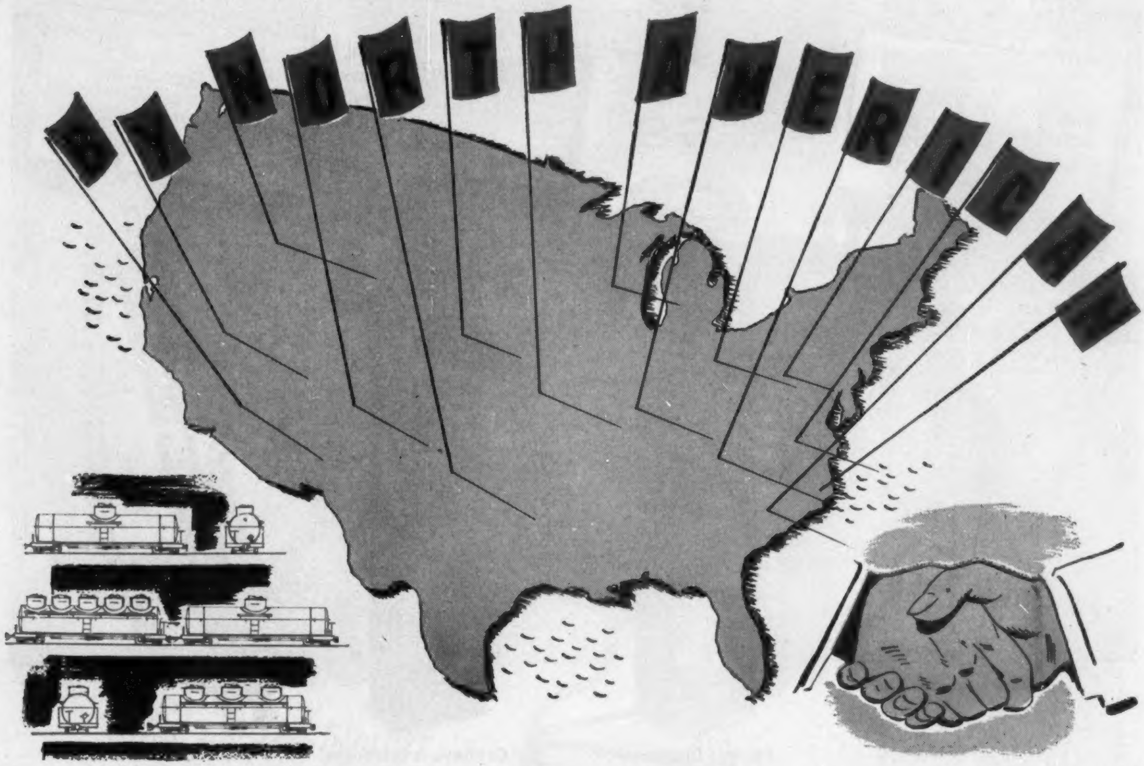

1. A big fleet of single and multiple compartment chemical cars that have been specially adapted and lined for customer requirements. (Special chemical cars will also be built for individual needs.)

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3. A very special understanding of chemical shipping problems and a background of close co-operation with the chemical industry.

It's a combination that delivers your bulk chemical shipments safe, clean, fast and sure wherever there's a railroad track—and at low cost! Let us know your requirements. You can depend on North American helpfulness and service.

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When hot, stagnant or fume-filled air distresses your men, your production suffers too.

Give men around furnaces or hot processes, or in confined areas, a steady supply of fresh, cool air with Coppus Blowers and Exhausters and watch their efficiency jump to a more profitable level.

There's a portable, easily adaptable Coppus "Blue Ribbon" product for practically any fresh-air requirement. The Coppus "Blue Ribbon" is the sign of precision workmanship and trouble-free, long-lasting operation. Check and mail the coupon for exact information. Sales offices in THOMAS' REGISTER. Other "Blue Ribbon" Products in CHEMICAL ENGINEERING CATALOG, REFINERY CATALOG, BEST'S SAFETY DIRECTORY, MINING CATALOGS.

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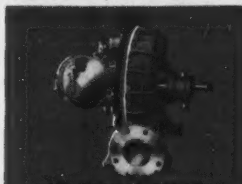

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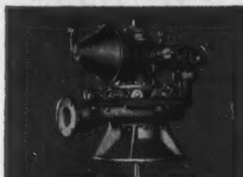
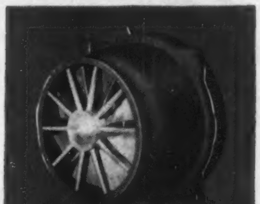
Six frame sizes —
1 to 150 horsepower



VERTICAL TURBINE
Six frame sizes —
1 to 150 horsepower



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MAIL THIS COUPON To Coppus Engineering Corp., 226 Park Avenue, Worcester 2, Mass.

PLEASE SEND ME INFORMATION ON SUPPLYING FRESH AIR TO MEN WORKING:

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√ **Product purification by absorption with liquid ammonia is a feature of a new partial oxidation process for acetylene. It was developed in Belgium by Societe Belge de l'Azote.**

√ **A nearly completed Bureau of Mines research project promises to solve the problem of removing silica from western alumina deposits. It indicates that economical production of alumina from anorthosite rock may be near.**

√ **Building has begun on plants to use a new hardwood pulping process developed by Sprout Waldron. It's said to use less total energy and show other savings over the chemigroundwood process.**

Another job for lead dioxide anodes

Japan's Sanwa Pure Chemical Co., Ltd., has developed an electrolytic process for producing bromates from bromides using a lead dioxide anode. First word on the process came last month at the Electrochemical Society meeting in San Francisco. Earlier, American Potash & Chemical Corp. revealed that it was pilot-planting an electrolytic perchlorate process using this type of anode (*Chementator*, April 1956, p. 103).

Present bromate processes use graphite anodes. These spall and form a mud that hinders continuous operation and gives yellowish, off-color bromate crystals. Lead dioxide appears to eliminate these problems.

In making its bromate Sanwa held its pilot cell at 160 F. to minimize anode loss and kept the pH below 10 to avoid producing oxygen. The cell operated at 3.5 v. and 525 amp. (180 amp./sq. ft.) and 1.74 kwh. was required per pound of potassium bromate produced. Sanwa reported an anode loss of 0.13 lb./ton of bromate and a 97% recovery without evaporation. Hydrogen discharging at the cathode caused sufficient circulation of the cell liquor.

But it was the lead dioxide anode and its preparation that stirred the meeting's interest, not the cell design nor the process. Sanwa has a unique, economical method for forming the anode without using a metal core, but it's keeping this to itself.

More on Udy processes revealed

Electrochemical Society's San Francisco meeting also heard details of a new electrothermic process for getting alumina and/or titanium dioxide from low-grade, high-iron siliceous ores (*Chementator*, May 1956, p. 103).

Discovered by Marvin J. Udy, this process and others (*Chementator*, Oct. 1955, p. 103 and April 1956, p. 104) are now being developed by Strategic-Udy Metallurgical and Chemical

Processes Ltd. Reynolds Metals, an aluminum producer, has taken an interest in the process and is also working on its application.

Udy's new process is based on close study of the phase diagram for the SiO_2, Al_2O_3, TiO_2 system. Essentially, he smelts calcined ores with coke at economical electric furnace temperatures—without adding lime or other fluxing material—to make low-carbon iron or steel and a slag containing silica, alumina and/or titanium dioxide. Sulfuric acid leaching recovers aluminum and/or titanium values from the slag.

It's possible to mix ilmenite and high-iron bauxite to make all three products. Even "red mud" from the Bayer alumina process could be used, though small amounts of silica must be added.

Whatever the starting material, process economics depend on realizing the ingot iron or steel values. But this should be no problem since ingot iron commands a higher price than pig iron. And Udy believes that a 450-ton/day plant could compete economically with the Bayer process.

For commercial production, theoretical power requirement is about 1,000 kwh./ton, but in practice this can be cut by feeding the calcined ore to the furnace at 1,830-2,000 F. Taking advantage of a liquid phase in the Al_2O_3-SiO_2 system at 2,810 F. and in the TiO_2-SiO_2 system at 2,800 F., Udy smelts the ores at about 2,900 F.—several hundred degrees lower than processes based on production of fused alumina.

New capacitor and two processes told

Other items of interest to chemical engineers which were discussed at San Francisco include:

• A revolutionary all-solid capacitor developed by Bell Labs and now going into production.

• A Bureau of Mines process for producing silicomanganese from low-grade native ores. (For earlier details see *Chem. Eng.*, June 1953, p. 122.)

• A columbium and tantalum concentration process developed by the Bureau of Mines.

The Bell development will be important to instrument, design and plant engineers. The new capacitor should find wide use in miniaturization and its rugged construction and desirable properties will fit it for many problem uses.

The unit has higher capacitance per unit volume than conventional capacitors, an extremely long shelf life and, with no liquid to boil or freeze, it can operate at both temperature extremes.

To make it, Bell sinters tantalum powder to form a highly porous (1,000 sq. cm./cc. of volume) slug coated with a thin dielectric film of tantalum dioxide. Manganese dioxide, which essentially replaces the liquid electrolyte, is then sandwiched in between the tantalum dioxide and a lead alloy anode.

The Bureau's silicomanganese process couples either heavy media separation or oil emulsion flotation with electric furnace smelting using hogged fuel (wood waste or sawdust) as reductant.

Tests indicate that 6,000 kwh or less would be required per ton of silicomanganese produced under commercial conditions, and that graphite electrode consumption would be less than 70 lb./ton. Use tests on the product in three steel mills prove it equal or superior to silicomanganese now available.

Differing magnetic susceptibilities of the mineral components keys the other Bureau process. Low-grade alluvial sands are scrubbed in an attrition scrubber to eliminate surface iron stains that would affect magnetic susceptibility. Slimes go to waste, sands to a low intensity wet magnetic scrubber where magnetite separates out.

Other components, mostly nonmagnetic at this stage, pass through a 2.8 amp. ring-type separator to remove ilmenite-garnet. Roasting the rest at about 1,500 F. for 2 hr. increases susceptibility. And passing through a series of magnetic separators progressively concentrates columbium- and tantalum-bearing minerals. The radioactivity of euxenite, most important and least magnetic of these minerals, provides a ready means of tracing its path and the paths of closely associated components.

Nitric acid replaces air oxidation

As a part of a multi-million dollar expansion program at its Belle, W. Va., works, Du Pont is going to boost adipic acid capacity by 75%. The new unit will use a nitric acid oxidation process rather than the batch air oxidation method now used at Belle.

Nitric acid oxidation processes have been

(Continued on page 108)

Actual laboratory pre-tests prove you can...

Blend liquids into dry materials fast, in one operation... without lumps

Getting perfect dispersions of liquids into dry materials without lumping has almost always entailed extra steps for pulverizing, mulling or screening, etc.

But P-K's new *Liquid-Feed** Twin Shell Blender eliminates those extra, costly operations. Now, in a one batch operation, you can achieve complete dispersion of liquids in a matter of minutes. Blender is charged through large dust-tight openings that allow easy access to shell interior for cleaning. Complete Liquid-Feed assembly is quickly removed by means of a spring loaded mechanism.

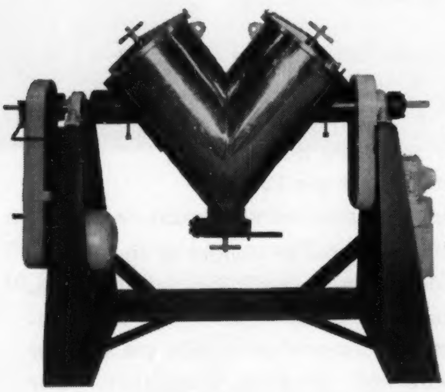
The Liquid-Feed blender is simple in concept. Liquid flows from a feeder tube within the bar onto a revolving distributing disc. Centrifugal force flings a fine spray outward. Dry materials tumbling in the Twin Shell receive liquid in controlled amounts at all times. The wire cage, spinning at high speed, prevents the formation of lumps before or after liquid is introduced.

Results? More perfect blends, in a fraction of time previously required. Want proof? P-K's Process Division maintains a complete lab to assure accurate, predetermined performance to meet your liquid-feed blending requirements. P-K will conduct, without obligation, laboratory test-blends with your materials.

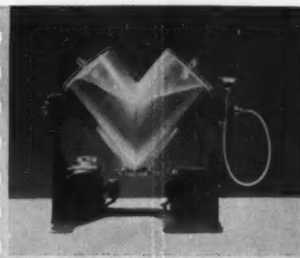
Experimental testing will provide operational procedure and scale-up data. All test reports are held in strict confidence when desired, and, whenever convenient, testing may be supervised or witnessed by your personnel. P-K will submit complete factual test results, including samples of test-blends. Write direct to our Research Department.

The Patterson-Kelley Co., Inc.,
160 Hanson Street, East Stroudsburg, Penna.

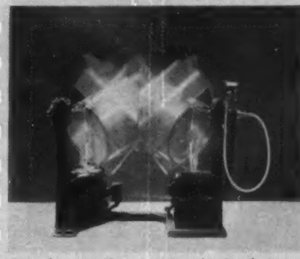
*patented and patents pending



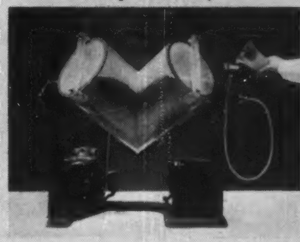
This production model is in stainless steel. Standard liquid-feed twin shell blenders are available in most commercial metals. Sizes range from 3 to 50 cu. ft. working capacity.



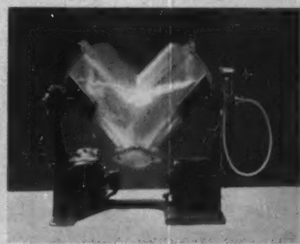
8 qt. blender is loaded for test with dissimilar materials, one lumpy and light, the other heavy and fine in texture.



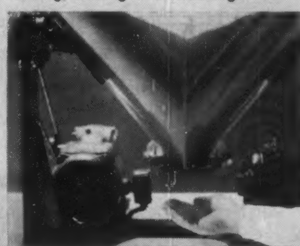
Complete uniformity is obtained in a few minutes by dry blending. Lumps are broken up by fast-spinning intensifier bar's wire "cage" assembly.



Liquids are then introduced into the dry blend during rotation by gravity-feed. Distributing disc disperses liquid evenly. Wire cage prevents clumping.



Average blending time is approximately 15 minutes to obtain perfect liquid-feed mix. One step operation eliminates pulverizing, mulling and screening.



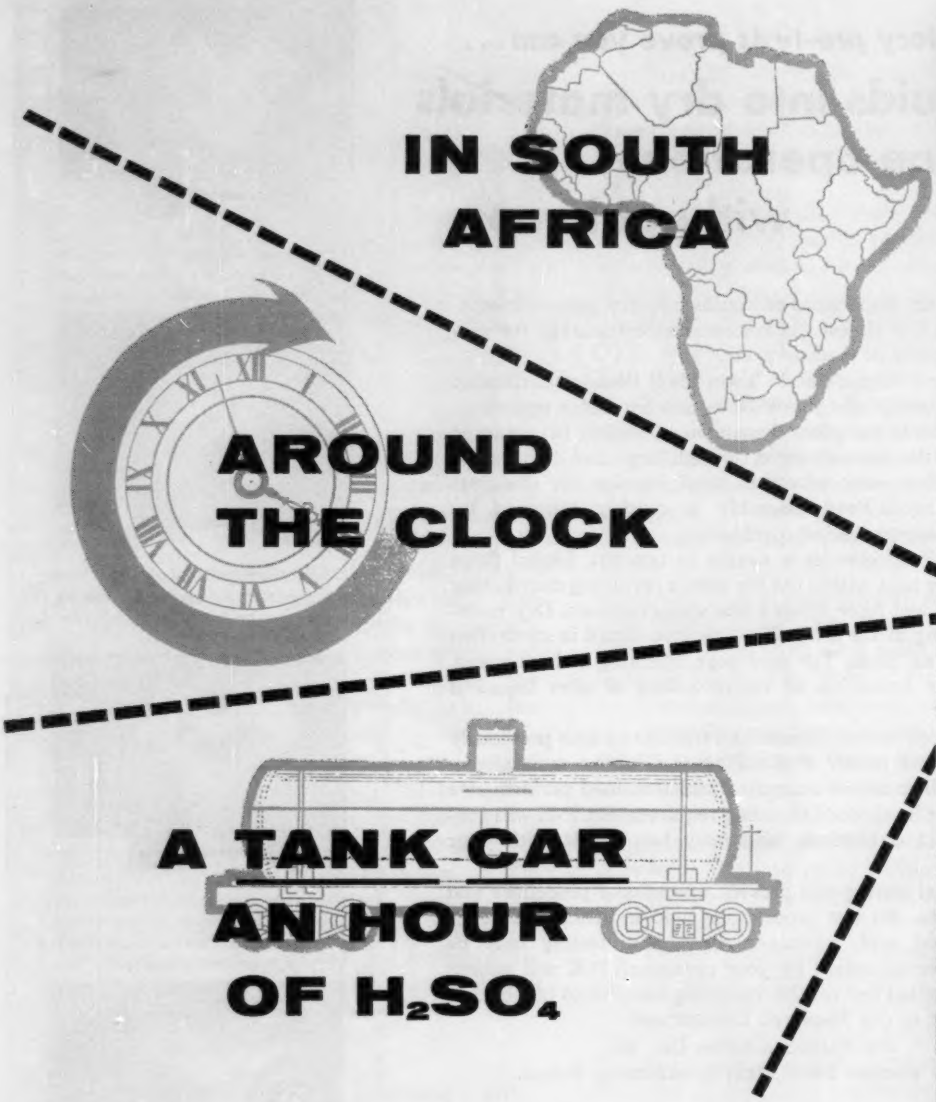
Discharging is easy. Stainless steel liquid-feed assembly ejects instantly, rinses in seconds. Seconds more to wipe clean the smooth, easy-to-get-at interior.

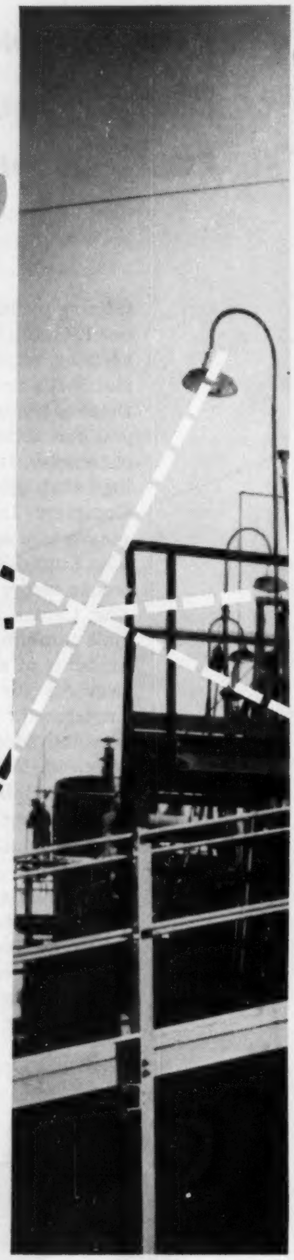
PATTERSON KELLEY

Chemical and Process Division

2599

Twin Shell Blenders • Autoclaves • Pilot Plants • Heat Exchangers
Ribbon and Double Cone Blenders • Lever Lock Doors





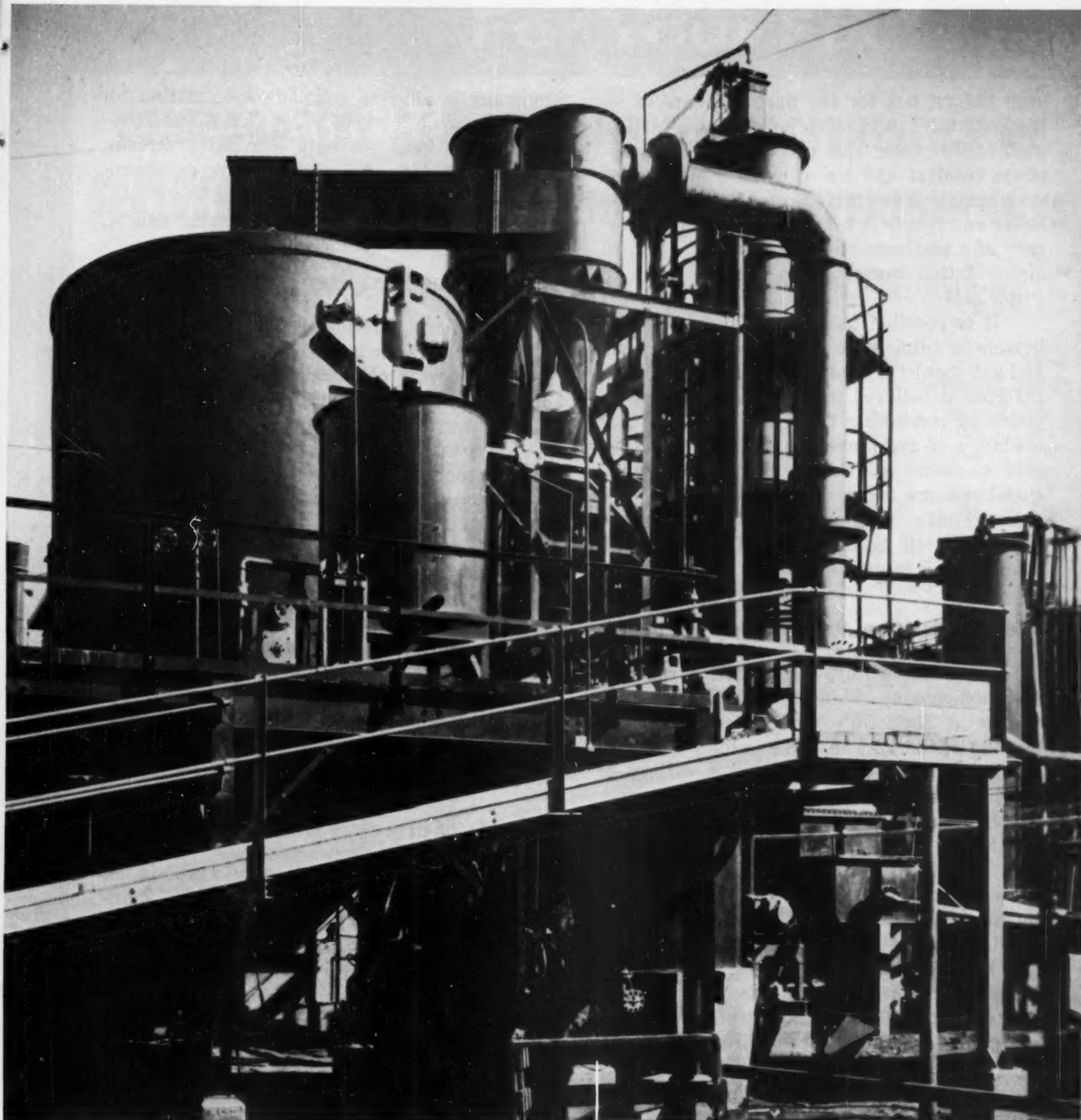
Over 1650 tons of H_2SO_4 — enough to fill twenty-four tank cars — are being produced every day for uranium leaching at seven South African mills.

An important part of each of these installations is a Dorrco FluoSolids System. Cumulatively the Systems include nineteen Reactors, of which sixteen were on original order and three on repeat orders, plus additional Dorr-Oliver and auxiliary equipment to produce a high strength SO_2 gas for acid manufacture by conventional contact acid plants.

Total feed to the Systems is 1450 tons per day of pyritic gold mill tailings — averaging 35 to 45% total sulfur, gas production is 75,000 to 82,000 SCFM. Gas strength averages 12 to 13% SO_2...sulfur recovery approximately 90%.

The efficiency and economics of the Dorrco FluoSolids System is in evidence in these facts. Additional representative proof that the FluoSolids process can produce an SO_2 gas at lower investment and operating costs than other roasters.

If there's a step in your flowsheet where inti-



mate contact between solids and gases is essential, fluidization should be investigated. Just drop a line to Dorr-Oliver Incorporated, Stamford, Conn.

This FluoSolids System at West Rand Consolidated Gold Mines, Ltd. on South Africa's fabulous Witwatersrand was started up early in 1952. The first of several to go into operation on the Rand, it was also the first in the world to combine FuoSolids roasting of pyrite with a contact acid plant.

FluoSolids is a Trade Mark of Dorr-Oliver Incorporated, Reg. U. S. Pat. Off.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U. S. A.

used before, but for the past 15 years or so Du Pont has stuck to air oxidation. Starting with cyclohexane, this process uses a liquid-phase catalyst and air to make a mixture of cyclohexanone and cyclohexanol, separates the latter and reacts it with more air in the presence of a platinum or silver catalyst. A third air oxidation converts the cyclohexanone to adipic acid.

It is possible to go directly from cyclohexane to adipic by oxidizing with nitric acid and get about the same yield. But the process Du Pont is believed to be installing increases yields by combining these two methods. Air oxidation of cyclohexane is followed by nitric acid oxidation of the resulting mixture of cyclohexanone and cyclohexanol.

Du Pont's earlier expansion of adipic capacity at its Sabine River, Texas, plant is also believed to use this route.

Wet combustion stops sulfide pollution

High-temperature air oxidation removes pollution-causing sulfides from processing wastes at Shell Oil's Wilmington-Dominguez (Calif.) refinery. The three units now in use handle up to 3,900 bbl./day of a variety of solutions, over a wide range of sulfide concentrations.

Shell's disposal process appears to be a first cousin to the Zimmerman process (*Chementator,* Dec. 1955, p. 103), developed by Sterling Drug Co. to handle spent wood-pulping liquors.

In the Zimmerman process, liquor enters a closed reactor with compressed air at about 800 psi. and 500 F. And both organic and inorganic pollutants are oxidized exothermically.

As A. G. Smith told the American Petroleum Institute's Montreal meeting a few days ago, Shell preheats its sulfide-bearing waters to about 160 F., adds air at 100 psi. and steam at 200 psi. and sends them to the reaction column. Both tray and packed columns—all were existing spare equipment—are used. They exothermically convert the sulfides to less objectionable thiosulfates which are discharged in water. Overhead gases contain some ammonia and hydrocarbons, so they are burned in a nearby furnace.

There's one sharp point of difference between the two processes. Shell's process is primarily designed to thwart pollution and, though a patent has been applied for, the company is offering complete information to other firms on a royalty-free basis. The Zimmerman process not only eliminates stream pollution, but it also supplies process steam or electricity and recovers pulping chemicals. So Sterling enforces a strict licensing policy.

Three strong oxidizers team up

Perchloryl fluoride, a powerful new oxidizing agent, is the latest entrant in Pennsalt's line of fluorine chemicals. Slated for many classified defense uses, the new product is also bidding for industry applications.

A colorless gas, ClO_3F is thermally stable at high temperatures, doesn't hydrolyze in hot water and decomposes slowly in alkali. Though it supports combustion, it is not incendiary and can be stored safely. To Pennsalt, these properties add up to a fine potential market. And while plans for a full scale plant have not yet been announced, the Calvert City area is already being looked on as the probable site.

To make the chemical, Pennsalt has adapted an Austrian process discovered in 1952. Essentially, it involves electrolyzing sodium perchlorate in a hydrogen fluoride atmosphere.

Variety of processes win zirconium bid

When the Atomic Energy Commission announced that it would pay a total of $75 million for 11 million lb. of reactor-grade zirconium over a five-year period, it turned a spotlight on three different chemical processes.

Each of the winning bidders on the contracts, National Distillers (1 million lb./yr.), National Research (700,000 lb./yr.) and Carborundum (500,000 lb./yr.), will build plants with an initial capacity of 1.5 million lb./yr.—well in excess of contracted amounts—and each will use a different process. Only one of these has been used commercially.

Carborundum, which will build at Parkersburg, W. Va., will use a Bureau of Mine-developed process (*Chementator,* May 1956, p. 108) to remove hafnium impurities and the Kroll magnesium reduction process to produce zirconium sponge (*Chem. Eng.,* Dec. 1954, p. 113). This is the same process which it has been using for nearly three years at its Akron, N. Y., plant. Observers feel that inclusion of the Kroll process among the contract winners

(Continued on page 110)

reflects AEC's reluctance to gamble everything on the newer methods.

National Distillers' new plant, set for Ashtabula, Ohio, will employ the Bureau of Mines hafnium separation process and a new sodium reduction process to make the sponge. National will probably use its new sodium dispersion technique, said to give a more uniform sponge. The process, which was proved in a 1,000 lb./day pilot plant and which will soon move into a semi-works operation twice as big, is reported to be most economical of all* because of the ease of handling liquid sodium as compared to solid magnesium and sodium's higher purity—which cuts losses. You can also look for National to use it to make other metals—titanium, for instance.

Little is known of the process National Research plans to use at its plant (to be built near Pensacola, Fla.,) other than that it will use nitric acid and ammonia. It is known that NRC has been working on a continuous arc dissociation process for zirconium and an electrolytic process, as well as the reduction methods. Best bet is that NRC will use its own hafnium separation technique, probably liquid-liquid extraction of the nitrates, and a sodium reduction step to make the sponge.

AEC also announced that the Bureau of Mines zirconium pilot plant at Albany, Ore., where the original process was tried, will be reactivated to make about 300,000 lb./yr. of the metal. Wah Chang Corp, one of the unsuccessful bidders on the major contract, will run it.

New air felting process to be tried

Several commercial installations of a new paper-making process are now being made and others are in prospect for later in the year. Invented by paper expert James d'A. Clark, the revolutionary air-based process is being developed and marketed by Fibrofelt Corp., Chicago.

Clark's process makes many kinds of fibrous sheets by depositing air-borne fibers from a cylindrical head to a moving wire screen. Advantages claimed include: Low capital investment compared to the conventional paper machine, ability to handle many types and sizes of fibers (including those too long for present paper machines yet too short for economical handling on textile machines), more random orientation of fibers, intermittent fiber charging (if wanted), ease of adding binding agents.

Heart of the process is the fiber depositing head. This is a horizontal cylinder about 16 in. in diameter and of almost any length. Fibers enter through a lengthwise slot near the top. Air, entering tangentially through a line of jets along the side of the cylinder, picks up the fibers and whirls them around the inside of the cylinder.

Fibers continuously exit through a screen or grid at the bottom and deposit on an endless wire belt running beneath the cylinder.

These heads can be placed in series to deposit a thicker batting or to make the same thickness faster. Importantly, this also permits simultaneous lamination of several different fibers.

Another Clark-developed process, this for making pressed boards from wood wafers, is also just going into commercial operation. Pack River Lumber Co., Sandpoint, Idaho, is installing it.

Chemical makers scent victory over OTC

U. S. chemical producers feel that they'll soon be able to claim a victory in their fight to block U. S. membership in the Organization for Trade Cooperation, the big international agency set up to administer the 35-nation General Agreement on Tariffs and Trade.

Several weeks ago an administration-backed resolution to approve membership cleared a House committee and it's expected to get House approval—after a floor battle. But observers now give the measure almost no chance to survive the Senate debate.

Leading chemical industry opposition are such groups as the Manufacturing Chemists' Assn., the Synthetic Organic Chemical Manufacturers' Assn. and the Rubber Manufacturers' Assn. Their criticism centers on both constitutional and economic issues.

The resolution's opponents feel that by accepting OTC Congress surrenders its power over tariff-making and delegates its lawmaking authority to a non-constitutional, international body. In addition, industry points out that it could use more, not less, protection from some imports.

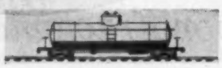
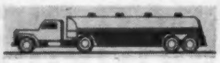
For more of WHAT'S HAPPENING......113

* National Distillers backed this up by being lowest bidder for the contract at a reported less-than-$5/lb. National Research bid at a reported $6.50/lb. Carborundum, with the only commercially proved process, bid at about $8/lb.

Shell Chemical announces—

EAK

ethyl amyl ketone

available now in  tank car and tank truck  quantities!

New high-boiling active solvent for nitrocellulose and vinyl lacquers

Now . . . to bring you even more flexibility in formulating . . . the Shell "Quality Group" of lacquer solvents includes *ethyl amyl ketone.*

EAK holds more nitrocellulose in solution at a given viscosity than any other high boiler commonly used.

In formulating a high solids lacquer, EAK will give you a low viscosity solution with exceptional diluent tolerance. EAK imparts superior properties of blush resistance, gloss and flow-out to coatings for wood or metal.

- **For automotive lacquers and thinners, EAK reduces the amount of rubbing, provides excellent gloss, thus adding to showroom appeal.**
- **For furniture lacquers, hot or cold spray, EAK provides good flow-out, leveling, blush resistance and freedom from bubbling.**
- **EAK has proved outstanding in making industrial maintenance vinyl lacquers, because of its high solvent power.**
- **In silk-screen printing lacquers, EAK gives freedom from screen-clogging.**

EAK has now taken its place in the family of Shell quality lacquer solvents that includes MEK, MIBK, and acetone. Write for technical bulletins for many suggested formulations.

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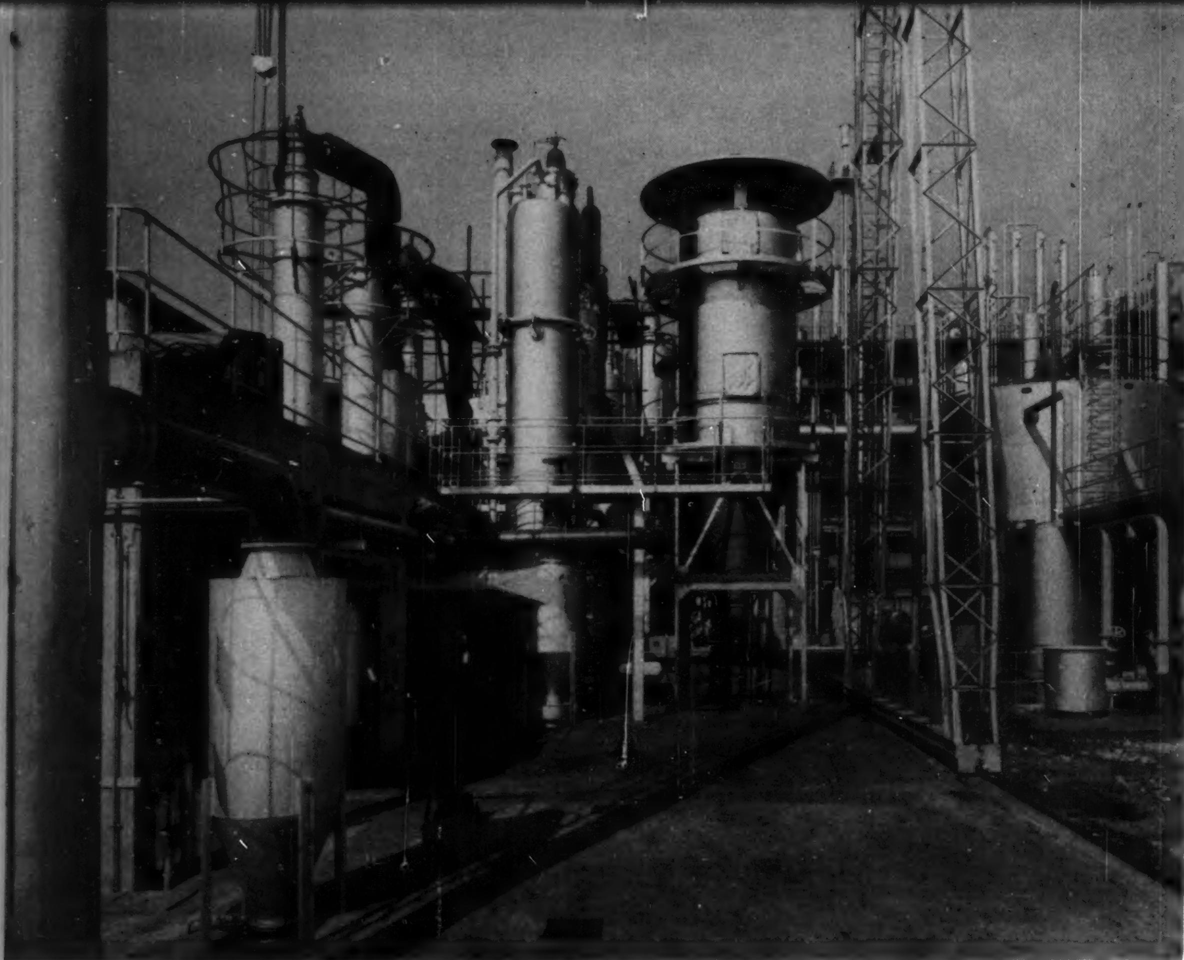
What's Happening

JUNE 1956 FEATURE NEWS



ACETYLENE is made via partial oxidation of natural gas in this Montecatini plant at Novara, Italy.

Acetaldehyde Plant Revamped for Profit

New process for making acetaldehyde from low-concentration acetylene yields right-of-way to production of pure acetylene for direct sale, added profits.

Early this year a new process for making acetaldehyde was to have had its first commercial test. As originally reported (*Chem. Eng.*, Dec. 1954, p. 103), Montecatini — largest Italian chemical manufacturer — had bypassed the need for purifying the acetylene used in the catalytic hydration to acetaldehyde.

Successful pilot-plant results had led to design of a process for the first large-scale plant that would selectively convert into acetaldehyde the acetylene from a carbon dioxide-acetylene mixture.

Mechanical design and fabrication began for a 33 ton/day acetaldehyde unit at Montecatini's Novara plant. Here a CO_2-acetylene mixture is available via the Montecatini version of BASF's partial oxidation of natural gas. Output of acetaldehyde is destined for manufacture of cellulose acetate rayon.

▶ **Then Came the Switch**—However, although Montecatini had achieved technical success with this new process, another—and more important—criterion of success slipped in between cup and lip.

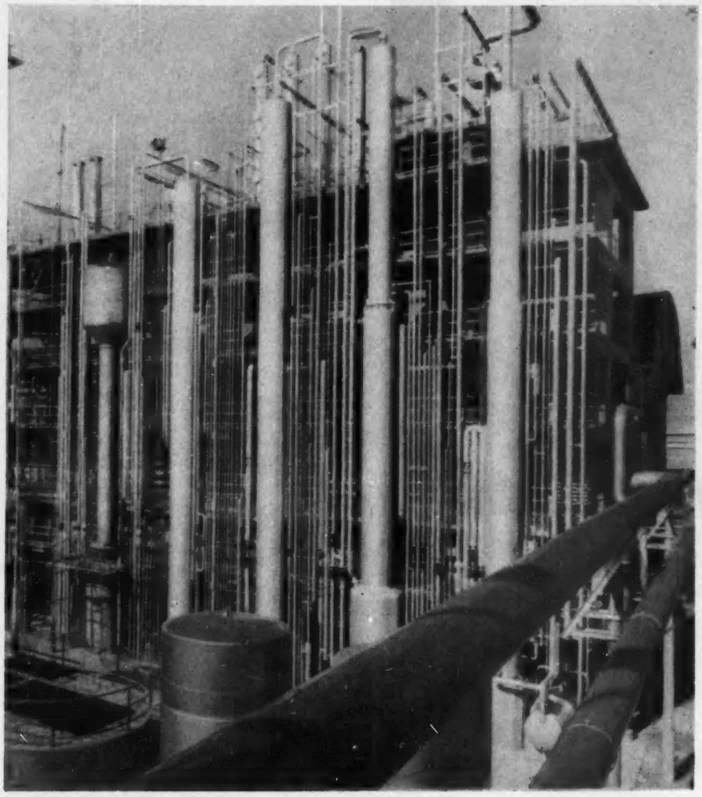
True, Montecatini engineers knew that they could make acetaldehyde from a mixture of carbon dioxide and acetylene, but management added another requirement.

Rising electric power charges in Italy are boosting the cost of producing calcium carbide for generating acetylene gas. Could the Novara plant separate a stream of pure acetylene for direct sale?

The answer was yes. But it meant extensive redesign of the process units and the scrapping of a chemical engineering achievement based on months of pilot-plant work.

Good economics is good engineering. The original design was scrapped.

▶ **Back on the Boards**—The



ACETALDEHYDE plant uses these absorption and distillation towers.

process went back to the design boards. Although the plant, when it went on stream this February, was more traditional than had first been planned, final design incorporates some novel features:

- Refrigerated methanol has been chosen as the selective solvent for absorption of pure acetylene.* (American engineers have favored other organic solvents, such as dimethyl formamide and butyrolactone, for this job.)
- Cold methanol absorption is coupled with a gas fractionation unit that recovers commercial quantities of ethylene and a synthesis gas mixture (carbon monoxide and hydrogen).
- After shift conversion giving additional hydrogen, the synthesis gas stream can be used to manufacture methanol as makeup for the process and for direct sale. Or it can be used for ammonia production.
- Gas leaving the absorption section at −70 C. can be fed directly to fractionation towers with no need for intervening compressors or other equipment. This reduces capital investment requirements and cuts down consumption of electric power.
- After refrigerated methanol absorption, the residual gas is practically free of acetylene. This reduces possible hazards in the fractionation towers.

▶Rest is Routine—From there on, Montecatini obtains acetaldehyde by the traditional route. Acetylene, in the presence of a catalyst, adds water to give crude acetaldehyde. The catalyst is composed of metallic mercury, a mixture of ferrous and ferric sulfates, mercurous and mercuric sulfates in dilute sulfuric acid solution.

The hydration takes place in stainless steel reactors, and purified acetaldehyde is obtained after final rectification.

* The near-secret Rectisol process of Lurgi and Blaw-Knox for purification of Fischer-Tropsch synthesis gas is also reported to use refrigerated methanol as an absorbent. In this application it absorbs carbon dioxide.

Masonite Expands; J-M Enters Field

Masonite Corp. has started a $14-million expansion of its Masonite hardboard plant at Laurel, Miss. At nearby Natchez, Johns-Manville, too, is building a plant which marks its entry into this field. Hardboard is a hard sheet material—used, for example, as backing for TV sets—made from pulpwood, formed under high pressure and heat.

Plant Sites Set for Low-Pressure Poly

A trio of licensees of the Phillips process for low-pressure poly, which can produce polyethylene or polypropylene or both, have announced sites for plants.

Celanese and M. W. Kellogg, both describing their proposed products as polyolefins, will build in Houston. The Celanese unit, to turn out 40 million lb./yr., will be completed early in 1957.

To make polyethylene as per Phillips, W. R. Grace has decided on Baton Rouge for its $18-million unit, expected on stream by mid-1957.

And Los Angeles County has been chosen by Koppers and Brea Chemical for their $10-million, 60-million-lb./yr. polyethylene plant, also low-pressure (Ziegler-licensed). In addition, Koppers reports that Woodbridge Township, Middlesex County, N. J., will be the site of another 30-milion-lb./yr. low-pressure plant which it plans to start up early in 1957. The company's decision to build a New Jersey plant was based on availability of raw material promised by Esso's ethylene recovery plant now being built in Linden, N. J.

In Australia, near Sydney, Imperial Chemical Industries of Australia and New Zealand will build a $6.3-million, 3,000-ton/yr. polyethylene plant.

DOW can analyze a six-component mixture in 2 min. for process control.

GLPC Catching On Fast

Gas-liquid partition chromatography, versatile new darling of the analytical laboratory, is now shucking its lab coat and donning plant operating gear.

A new technique for separation and analysis of mixtures of gases and liquids is sweeping across the country like wildfire. It's called gas-liquid partition chromatography.

Though first work on putting the GLPC principle to practical use began only five years ago in England, almost every major U.S. chemical and petroleum company today is actively studying or using techniques involving GLPC.

Within the past year at least four U.S. manufacturers—Perkin-Elmer, Fisher Scientific, Podbielniak, Burrell Corp.—have come out with commercial instruments which exploit this principle. Two more will shortly come out with units: Beckman and Consolidated Electrodynamics.

Such companies as Monsanto, American Cyanamid, Dow, Rohm & Haas, Gulf Oil, Shell Development, Tennessee Eastman and Esso have built their own GLPC apparatus, and at least one firm—Shell Chemical—has under way an installation in which GLPC is used for automatic process control.

▶**Features of GLPC**—What's GLPC got that merits such attention? As expressed by an instrumentation specialist for one of the nation's largest chemical companies:

"Potentialities of gas-liquid partition chromatography for automatic process stream analysis, as well as for control and research laboratory purposes, are tremendous. It may well displace current analytical instrumental techniques in many applications.

"Major advantage is versatility. It is potentially applicable to the analysis of any vaporizable sample in a concentration range down to parts per million.

"The equipment is simple and inexpensive. We expect plant instrumentation to cost much less than comparable infrared equipment." (Cost of GLPC installations ranges between $1,000 and $7,000; infrared analyzers are up around the $15,000 mark; mass spectrometers, $40,000 plus cost of a building to house them in many cases. GLPC installations don't require professionally trained individuals to operate them as do the other methods.)

"While its speed at present cannot compare with optical analytical methods, there appears to be hope for improvements in this respect." (Compared to distillation, GLPC takes minutes instead of hours or days.)

▶**Lots of Support**—These opinions were echoed by all companies which CE's editors contacted during preparation of this story. Most of them have recently presented, or are preparing, technical papers based on their own particular experiences with the new technique.

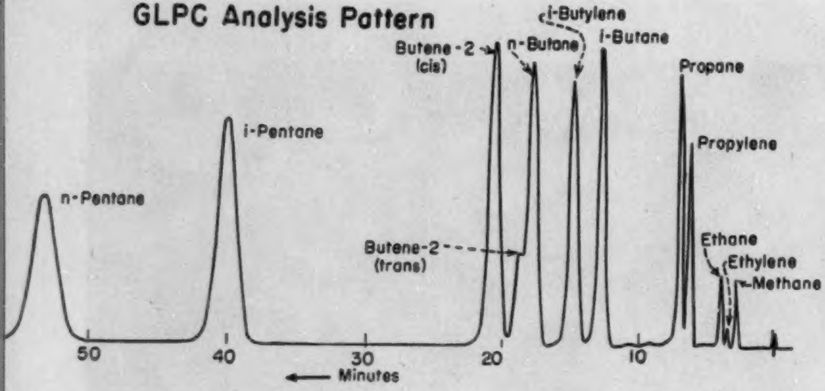
The wide range of applications for GLPC can only be suggested by the following materials which it easily separates and analyzes (qualitatively as well as quantitatively): C_1 through C_{18} components, including traces; low-boiling alcohols, aldehydes, ethers, esters, amines, amides, fatty acids; primary, secondary and tertiary substituted hydrocarbons; saturated and unsaturated compounds such as cyclohexane, cyclohexene, pentanes and pentenes; water in hydrocarbons; halogenated materials; aromatics in catalytically reformed gasoline.

▶**For Automatic Control**—Shell and Esso, among others, have worked on ways to adapt GLPC instruments to automatic process-stream analysis.

Nine units made by Shell Development at Emeryville, Calif., have been distributed to Shell Oil and Shell Chemical installations throughout the country. Esso has laboratory units identifying 3- to 5-carbon paraffins for process control in catalytic reforming of naphthas.

Rohm & Haas researchers have been using GLPC for qualitative identification of trace impurities, e.g., methyl propionate, benzene and ethyl acrylate, in methyl acrylate;

GLPC Analysis Pattern



Cyanamid is evaluating catalysts via GLPC.

Low cost, simplicity and relative speed of GLPC yield impressive process control economies, move adequate control within practical reach of many small plant operators. Separations of even the most complex mixtures (which might require more than a day to distill) seldom take as much as a half hour. Results are immediately available; there's no need for data-reduction units or long manual calculations which sometimes delay completion of spectrometer analyses.

And gas chromatography avoids many of the pitfalls of precision distillation techniques, like azeotrope formation and small differences in boiling points. Separations impossible to achieve by vacuum distillation and extremely difficult with a mass spectrometer—like that of a total C_4 fraction—are the work of a few minutes for GLPC.

▶ **Basis of GLPC**—Separations are based on differences in "partition coefficients" of components in a gas or liquid mixture. The partition coefficient is the ratio between the concentration of component in the gas phase and its concentration in a liquid phase.

The mixture is exposed in vapor form to some selected solvent. In current practice, the solvent is spread in a thin film over the large surface area formed by 100-mesh granules of an inert material like diatomaceous earth and is packed in a column. Each component of the mixture—moving through the column in a carrier gas—partitions between its vapor phase in the spaces between the granules and a liquid phase dissolved in the solvent. In a given system, affinity of the component for the dissolved state is characteristic to it alone and to no other component.

▶ **Absorption Keys Versatility**—So, unlike other more familiar forms of chromatography, which depend primarily on the single surface phenomenon of adsorption (of a gas on a solid, for example) the key to GLPC is absorption.

Absorption, of course, can involve any of the whole complex of mechanisms of various solution interactions—polarity, Van der Waals forces, hydrogen bonding or other chemical reactions. This complex of mechanisms gives GLPC its versatility and universality.

For a given separation problem, you can choose a solvent (e.g., silicone oil, dioctyl phthalate, diglycerol) which makes most use of that mechanism emphasizing the distinction between components and so gives the cleanest separation. For example, by choosing the right solvent, you can influence the differential vapor pressure between components as to separate closely boiling or azeotrope-forming mixtures.

▶ **GLPC in Practice**—Typically, you have a column filled with the inert solvent-coated packing. Into this column you inject a fraction of a gram of the mixture of gases to be analyzed. An inert carrier gas, such as helium, sweeps the sample through the column.

Any pure compound will travel through the column at a speed determined by its partition coefficient. The sample mixture consequently separates into its individual components, each moving at a different rate.

The compound with the largest gas/liquid phase ratio emerges first, followed at intervals by other components. If pressure and rate of flow of the carrier gas, temperatures of the column and detecting system, and composition of the packing are not changed, the retention time before any particular component leaves the column will also be constant. This time is determined experimentally from a sample of the pure compound, then used to identify that compound in subsequent analyses.

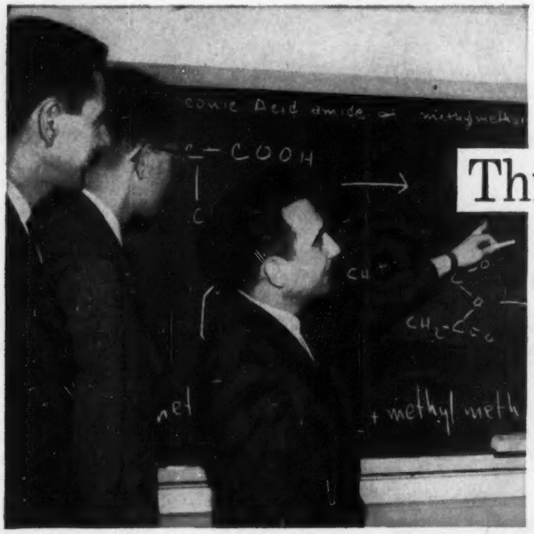
▶ **Quantitative and Qualitative**—Often, a low-current, thermistor-type thermal conductivity cell is used to detect and measure the emerging vapors. When only carrier gas is flowing through the column, the cell is in balance and the recorder draws a straight, flat baseline. As soon as any other compound appears in the gas, the cell is unbalanced and a "peak" appears on the chart.

Each resolved component gives a separate peak, high if the quantity is large, low if there is only a little in the mixture. The time at which each component appears on the chart identifies it. The area under the peak is a function of its molal concentration.

Use of the elution technique for moving mixtures through the column allows the instrument to handle successive samples with no delay in between. This, of course, contributes to its adaptability to semicontinuous production-line use. Accuracy of the method is limited only by that of the detector.

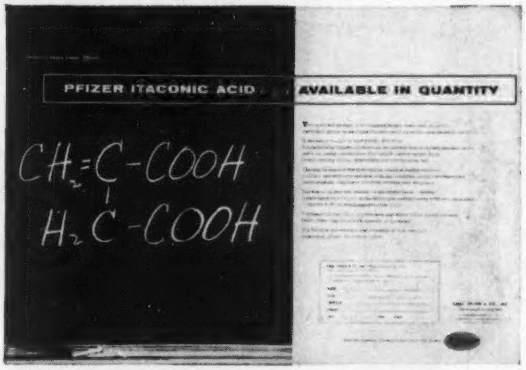
▶ **Scale-up for Production**—Though immediate applications for GLPC lie in the field of analysis, its more distant possibilities as a plant-scale separation tool have not been ignored.

The point at which present design of apparatus becomes too cumbersome and unecono-



"**Pfizer team probes low-cost fermentation to make industrial itaconic acid...**
enthusiasm among potential customers is running high...early investigators are unanimous in agreeing that it's a highly versatile building block."—from Chemical Week, April 2, 1955.

This was April, 1955...



Then this announcement of the availability of itaconic acid brought hundreds of requests for samples.*

AND NOW,
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Pfizer Itaconic Acid

● Through the development of a new high-purity technical grade of Pfizer Itaconic Acid, it is **now possible to purchase this versatile chemical at approximately twenty-five per cent less than before.** (The refined grade is, of course, still available and its price has been markedly reduced.)

All this means that your production men should take a close look at the advantages your chemists have found in this versatile compound.

Two carboxyl groups, a conjugated double bond and an active methylene group make Pfizer Itaconic Acid a reactive and versatile molecule.

It esterifies readily in high yields. Esters of low-molecular weight alcohols can be polymerized and fatty alcohol esters serve as useful plasticizers. Polyhydric alcohol esters form thermosetting resins. Monoesters can also be prepared.

The double bond of the acid and its esters is highly reactive; addition polymers are possible with acrylonitrile, methyl methacrylate, vinyl chloride, vinylidene chloride, styrene and butadiene.

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mic has not yet been determined, but it is known that columns could easily turn out 100 g. of product. Production of certain pharmaceuticals or of pure hydrocarbons for use as standards might well be economic via today's GLPC techniques.

However, it may be that for any substantial scale-up to production level, chemical engineers would have to approach application of the GLPC principle from an entirely different direction than that taken by designers of the present analytical equipment. •

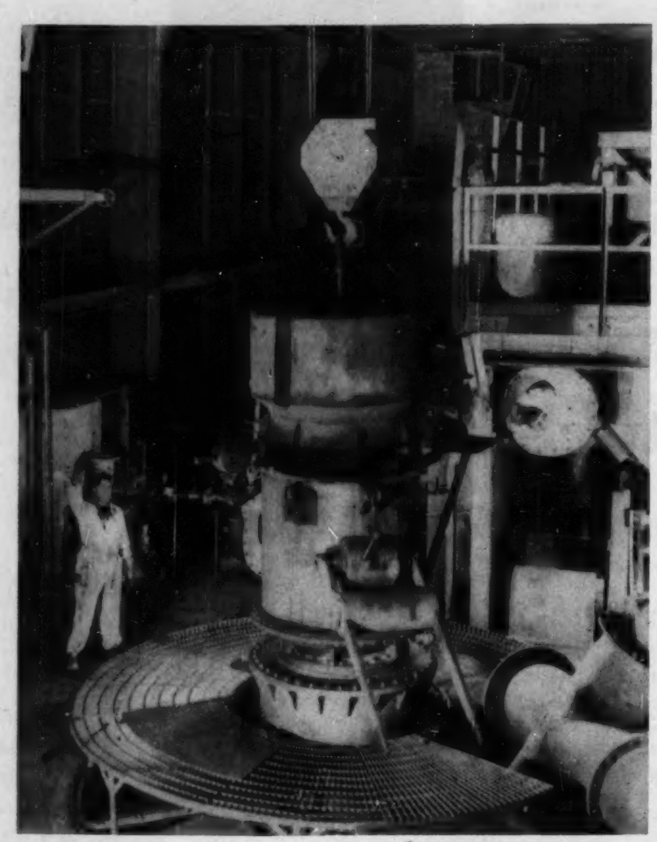
Released: Sun's Energy Stored 60 Miles Up

An Aerobee rocket, equipped to release nitric oxide gas under high pressure when sent to an altitude of 60 mi. above Holloman Air Development Center, N. M., recently scored the first success in releasing the energy chemically stored by the sun in the upper atmosphere, according to an Air Force report.

By boosting the natural amount of nitric oxide in the atmosphere by a factor of several billion, gas released by the rocket produced a spot of light in the upper atmosphere which spread to about three miles before it thinned out and its brightness dimmed.

Nitric oxide has the property of bringing two oxygen atoms together to form an oxygen molecule and release a huge quantity of energy. The gas is not consumed in the process but is used over and over. The process occurs in nature, but the natural abundance of nitric oxide gas is so small that its glow in the sky can be detected only by sensitive instruments.

The experiments, carried on by Air Research and Development Command, may conceivably lead to means of extracting this energy for such uses as the propulsion of rocket ships high in the earth's atmosphere.



Ti Ore Goes to Chlorinator at Plant Set for Expansion

A 67% expansion of titanium sponge production at Titanium Metals Corp. of America's plant at Henderson, Nev., will raise output from 3,600 to 6,000 tons/yr. by the end of 1956. Ingot-melting facilities will be expanded proportionately. New production units will be built independent of government contractual guarantees. Nonmilitary Ti uses, which have risen with the 1 to 10 ton/day increase in Henderson's production since 1951, are expected to expand even faster in the future.

Two Oil Firms Will Build Ammonia Plants

Texas Co. and Petroleum Chemicals, Inc., each have plans for new anhydrous ammonia plants to cost in the neighborhood of $12 million apiece. Texas Co.'s plant, which will also produce ammonia derivatives, will be located at its Lockport, Ill., refinery. Petroleum Chemicals, jointly owned by Cities Service and Continental Oil, will locate its 100,000-ton/yr. plant at Lake Charles, La. Most of its output will be sold for fertilizer. Completion is set for fall 1957.

Also at Lake Charles, another affiliate of Continental Oil—the newly organized Lake Charles Chemical Co.—will build a $6.25-million coking unit. To be completed late in 1957, it is designed to upgrade Conoco's Lake Charles refinery stocks now used in making heavy fuel oil. It will produce about 85,000 tons/yr. of coke for industrial use and 4,200 bbl./day of refinery stock for motor gasoline.

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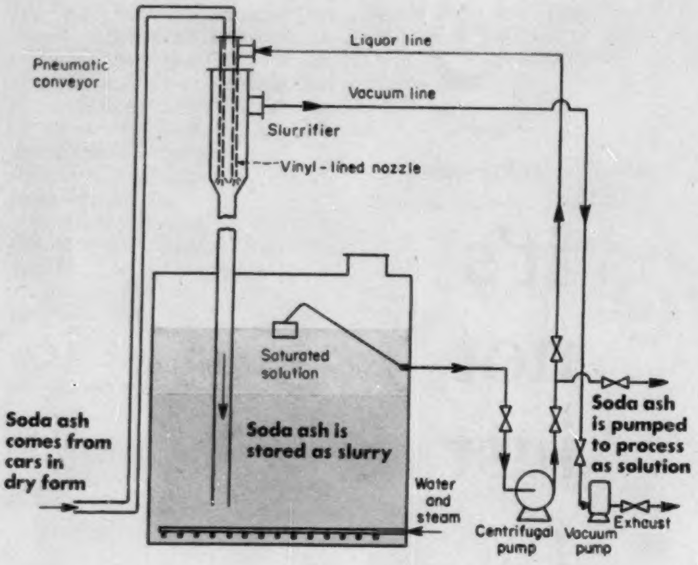

Slurry Storage Saves Space

Soda ash in slurry form takes less space, offers handling and process advantages. But capitalizing on these features demands careful design of facilities.

To any soda ash user who plans to install new or additional storage facilities, the economy of slurry storage far outstrips that of dry or solution systems. Only requisites are that:

- The soda ash is destined for use in solution form.
- Annual consumption is more than 400 tons.

▶**Showing the Way**—Such, at least, is the belief of Diamond Alkali Co. For evidence, the company points to a rapidly growing roster of firms for whom Diamond has designed slurry storage systems within the past couple of years. These include: Lithium Corp. of America, Bessemer City, N. C.; Great Northern Paper Co., East Millinocket, Me.; Hammermill Paper Co., Erie, Pa.; Electric Autolite Co., Sharonville, Ohio; Reheis Co., Berkley Heights, N. J. (manufacturer of antacids).

Paper companies in particular (Union Bag & Paper, too, has slurry storage facilities at Savannah, Ga., designed by Olin Mathieson) may serve as a straw in the wind. Though at present the largest percentage of light soda ash handled in bulk is still stored in the dry state, irrespective of end use, papermakers represent an industry block whose need for soda ash in solution form—and, of course, for added storage facilities—has recently risen sharply. This is because of large-scale consumption of soda ash in new semichemical plants for producing paper from hardwoods.

▶**Density's the Thing**—Among the benefits of slurry storage:

- *Reduced storage space* — In a properly designed system, slurried soda ash is in the monohydrate form, with a density of 56 lb./cu. ft., compared to 35 lb./cu. ft. for dry ash or 25 lb./cu ft. for ash in solution.
- *Lower tank costs*—Because more ash as slurry can go in a given space, the number and size of storage tanks are considerably lowered.
- *Readily usable form*—Supernatant liquor in the tank, which is what goes to process, is saturated (30% soda ash) and of uniform concentration. If desired, solution can be diluted automatically as used. Or when the solution is to be reacted and reaction products evaporated for water removal, use of saturated liquor reduces the quantity of water which must subsequently be removed.

In addition, because the slurry tank functions as a combination storage and dissolving tank, it eliminates the need for such auxiliaries as a transfer conveyor, a separate dissolving tank and a mixer to produce the solution of soda ash.

- *Superior efficiency*—Storage-to-process handling efficiency gains the time-proven greater ease that goes with a switch from dry to liquid materials handling. (Handling costs from hopper car to storage tank are identical for dry and wet systems.)

▶**Reserved Endorsers**—In contrast to Diamond, endorsement given slurry storage by such soda ash marketers as Olin Mathieson, Solvay and Wyandotte is somewhat reserved. Conditions under which they'll recommend and engineer slurry systems are more restricted.

Olin Mathieson, for example, suggests that they are best confined to consuming plants which must carry inventories of from 500 to 3,000 tons. Others declare that the economy of slurry storage leans heavily on the availability of equipment which can be adapted to slurry service, or to the location of the unloading siding with respect to storage and consuming areas.

And there's some feeling among consumers that economical slurry storage is possible only in warm climates. To keep soda ash in slurry form, i.e., as monohydrate, tank contents must be kept between 105 and 120 F.

▶**Diamond's Wholehearted** — Diamond attributes its confidence in the broad and profitable usability of slurry systems to the company's own engineering

Reports indicate 2½ times longer finish life from polish using A-C POLYETHYLENE.

There's a big change in polish!

Polish manufacturers are upgrading all types of wax formulations by using A-C POLYETHYLENE, the low-molecular-weight polyethylene. Higher luster and better scuff resistance are just two of the ways that A-C POLYETHYLENE improves polish.

Liquid floor polish formulas get excellent wet traffic resistance and anti-slip properties from this new polymer. The high luster is easily restored to original brilliance with dry mopping.

Furniture polish, automobile polish, shoe polish and coatings for floor coverings and many other materials all benefit from important improvements in finish and ease of production.

A-C* Polyethylene

- A-C POLYETHYLENE is compatible with all wax formulations.
- A-C POLYETHYLENE is available in regular or emulsifiable grades. It can be emulsified in acid, neutral or alkali systems.
- A-C POLYETHYLENE is a manufactured product in plentiful supply. Delivery is on-time and prices are stable.

For every type of polish, in every type of application, your formulations will be upgraded by the use of A-C POLYETHYLENE. Try it and profit. Commercial quantities are available for your immediate evaluation. Write for free samples or literature today.

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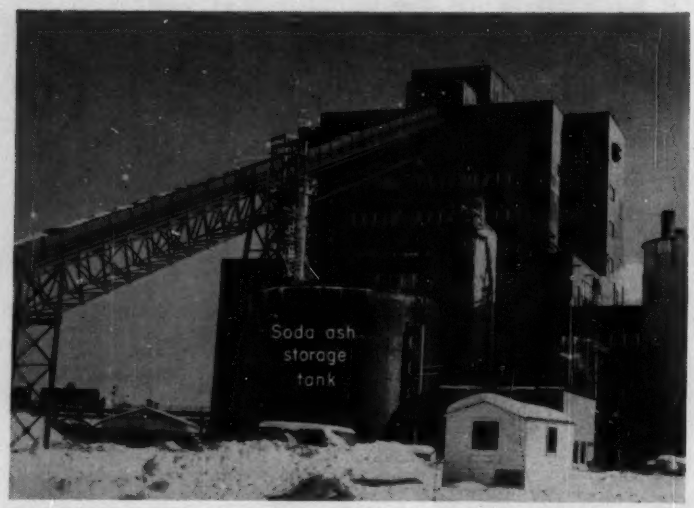
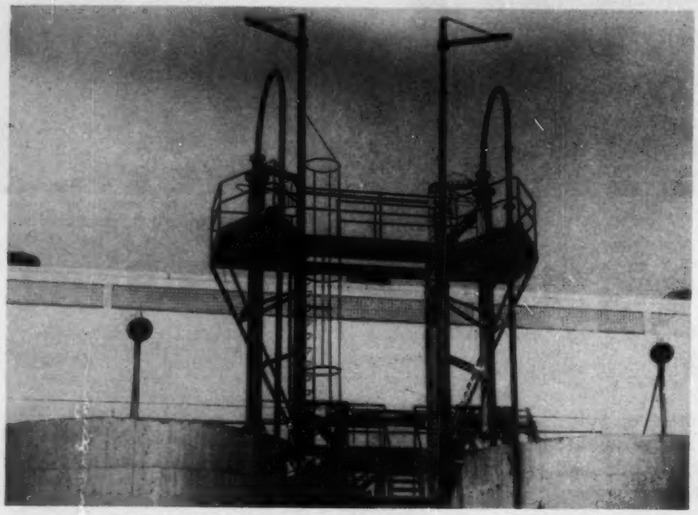


SEVERE Maine climate at Great Northern's mill is no deterrent.



CLOSEUP view shows soda ash slurrifiers at Lithium Corp.'s installation.

know-how and a few patented equipment refinements. These refinements take care of problems which might otherwise cancel out expected benefits:

- A "slurrifier" box, part of the pneumatic unloading system, mixes dry ash with liquor in the proper proportions at the proper rate. Formation of the desired monohydrate, without lumps, is immediate, and it can enter the storage tank without delay.
- Specially designed sparger nozzles at the tank bottom introduce fresh water required when saturated liquor is drawn off to process from the top. Spaced at carefully calculated intervals dictated by size and shape of the particular tank, the nozzles intimately mix slurry and water to form saturated solution, which immediately percolates up to the top of the tank. Their design guards against channeling by trickling water in, and against clogging or backwash of monohydrate into the water pipes.
- Know-how as to sizing and insulating the slurry tank makes external heat requirements very low. Considerable heat evolves during solution of the soda ash in water and its conversion to monohydrate. In an average installation, temperature rises about 60 F. during the slurrying process, usually enough to increase slurry temperature above the 95.7 F. transition-to-monohydrate point. If added heat is needed, steam can be introduced via the sparging nozzles.

▶**Satisfied Users** — Good examples of satisfied customers are Lithium Corp. of America and Great Northern Paper Co. Both have been successfully operating slurry storage systems for more than a year.

Lithium Corp. required two seven-car (total: 98,000 lb.) storage tanks, each with 74,000-gal. capacity. Best dimensions were found to be 24 ft. dia. by 22 ft. high.

To transfer dry ash to a tank, air is sucked through the ports of Diamond's patented unloading hopper attachment. Thus fluidized, ash is carried through a flexible hose and vertical line to the slurrifier.

▶**Nozzles Smooth Kinks**—Here the pipe carrying ash becomes the innermost of a nesting of three pipes. Into the annulus surrounding this pipe is pumped recycle liquor from the storage tank (or water, if the tank is empty). To meet the ash coming through the inner pipe, liquor must go through a nozzle which forms a spray. This liquor curtain scrubs ash from the air stream (air is here removed through the vacuum line), washes the resultant slurry down the outermost pipe, which continues into the tank. Big factor in the nozzle's successful performance is its smooth vinyl inner surface, which prevents ash from sticking and thereby avoids cake formation and clogging.

The monohydrate formed is, of course, denser than the solution and settles rapidly, making available a clear, saturated supernatant liquor. Maximum loading of tank comprises 92% of its volume as slurry, leaving only 8% clear solution on top. A floating swing joint picks up liquor for process or recycle.

Sparging nozzles at tank bot-

tom, which admit water to keep the tank's contents at the 92-to-8 proportion, are, in Lithium Corp.'s case, placed in a gridiron configuration for best results. About 88 are spaced at uniform intervals. Each nozzle consists of a ⅜-in. perforated, dead-end pipe about 4 in. long. A rubber sleeve over the pipe expands to admit a trickle of water, contracts when flow is stopped to prevent backwash of slurry and clogging of the perforations.

Great Northern's installation is similar. There is one tank, 34 ft. high by 40 ft. dia. The unloading and slurrying system operates at 18 tons/hr. of soda ash. In particular, its success gives the lie to the notion that warm weather is necessary for economical slurry storage. Located in the severe Maine climate, the outdoor tank is often surrounded by snow.

All-Electronic Controls For New Chemicals Still

New plant facilities, which will triple Truland Chemical Co.'s distilling and refining capacity for organic byproducts and residues, are controlled by electronic instruments which rely in no way on pneumatic components. It is believed to be the first all-electronic, plant-control system in the world. Located at East Rutherford, N. J., and due for startup this summer, the new plant supplements Truland's 100,000-gal./mo. Union, N. J., operation.

Climax Doubles Mo Catalyst Output

Spurred by a three-year market increase of almost 300%, Climax Molybdenum Co. is doubling the 2.7-million-lb./yr. capacity of its high-purity molybdic oxide plant in Langeloth, Pa. Principal outlets for the product are as catalysts in petroleum reforming and desulfurization processes and as a source of molybdenum metal for powder metallurgy and superalloys.

To make the pure oxide, Climax starts with molybdenite concentrates (MoS_2) from its Colorado mine and mill, roasts them to get technical molybdic oxide. Because molybdic oxide volatilizes above 1,100 F., the pure oxide is produced by sublimation. Technical oxide, fed into a Globar-heated rotary-hearth furnace at 2,000-2,150 F., vaporizes, and the sublimed MoO_3, is swept out of the furnace into bag filters.

The exceedingly fine, light product, averaging over 99.5% MoO_3, is then densified about seven times in a pug mill with a minimum amount of distilled water and finally dried and milled.

New Process for Potassium Borohydride

Using sodium hydride in oil dispersion and methyl borate as intermediates, Metal Hydrides Inc., Beverly, Mass., has developed a new commercial process for making potassium borohydride. Cost and yield analysis of a six-month pilot-plant study prompted the company to initiate commercial production of several hundred pounds per day.

The compound is used as a high-yield reducing agent for the carbonyl group of aldehydes and ketones in aqueous solution and with lithium chloride to reduce esters.

Big New Natural Source For Insulating Board

To produce insulating board for Western markets, Johns-Manville is backing its discovery of a big new raw material source in the vicinity with a $12-million investment for a plant and timberlands near Klamath Falls, Ore. To utilize groundwood from vast forested areas of relatively worthless lodgepole pine, the plant will consume 50,000 cords annually.

About the first major use for this type of timber, processing will be similar to that used at J-M's Jarrett, Va., and North Bay, Ont., plants, which draw on Southern pine.

U. S. Foresters estimate that the general region could produce about 287,000 cords annually on a sustained yield basis.

Convention Calendar

12th Chemical Apparatus and Equipment Congress and Exhibition, Dechema, Frankfurt am Main, Germany, May 31-June 8.

Forest Products Research Society, 10th national meeting, Asheville, N. C., June 4-7.

American Society for Quality Control, 10th annual convention, Palais du Commerce, Montreal, June 6-8.

Society of the Plastics Industry, Seventh National Plastics Exposition, Coliseum, New York, June 11-15.

Gordon Research Conferences; American Assn. for the Advancement of Science; "Organic Reactions and Processes," "Properties of Metals at High Temperatures," "Lipide Metabolism"; Colby Junior College, New London, N. H., New Hampton School, New Hampton, N. H., Kimball Union Academy, Meriden, N. H.; June 11-Aug. 31.

American Society for Testing Materials, 59th annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J., June 17-22.

World Power Conference, fifth plenary meeting, Vienna, Austria, June 17-23.

Third Annual Material Handling Training Conference, Fee: $850, Lake Placid Club, Lake Placid, N. Y., June 17-30.

Atomic Energy Conference, Atomic Industrial Forum and the Denver Research Institute, "Uranium and the Atomic Industry," Cosmopolitan Hotel, Denver, June 25-26.

Stanford Research Institute, symposium on "High Temperature—A Tool for the Future," University of California, Berkeley, Calif., June 25-27.

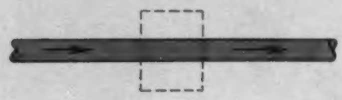
Society of the Chemical Industry, 75th annual meeting, Belgrave Square, London, July 9-14.

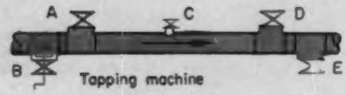
British Plastics Exhibition & Convention, British Plastics Federation, Grand Hall, Olympia, London, England, July 10-20.

Ammonia Plant Shuns Costly Shutdown

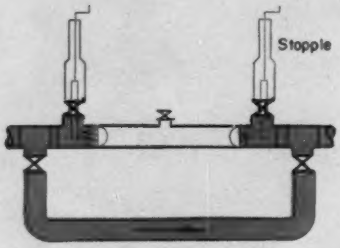
Here's how one chemical plant tied new equipment into going operations without missing a step. Special tools and techniques made it possible.

Problem: Install new gas separator without interrupting flow

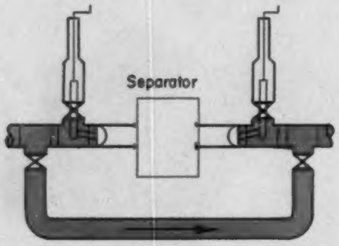




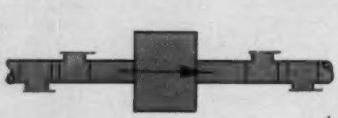
- Install five tees and valves
- Tap line at each tee



- Install bypass line
- Cut off main flow with stopples



- Remove section of main line
- Install separator



- Remove stopples and bypass line
- Insert plugs in fittings
- Salvage valves

GRACE CHEMICAL Co.'s new ammonia plant at Memphis claims distinction as first chemical plant to "discover" the Williamson Stopple. Grace engineers recently used Stopples and other Williamson equipment to avoid an emergency shutdown during a period when the plant could ill afford to lose four or more days of production.

As described in this month's Process Equipment News, (pp. 288-292), the Stopple is a device developed by T. D. Williamson, Inc., primarily for the oil and gas pipeline industry. Pipeliners have used Stopples successfully to isolate sections of lines while tieing in new compressors or pumping stations. Stopples permit these connections to be made without shutting down and with the lines under full pressure.

▶**Grace's Dilemma**—Within a few weeks after starting up its ammonia plant, Grace Chemical (division of W. R. Grace & Co.) found that its synthesis gas purification system was imperfect; oil was getting through and fouling the low-temperature exchangers in the liquid nitrogen scrubbing unit.

Plant management faced this dilemma:

- Shut down for at least four days to install the needed purification equipment.
- Or run without this equipment and face an inevitable shutdown of much longer duration to derime and solvent wash the exchangers.

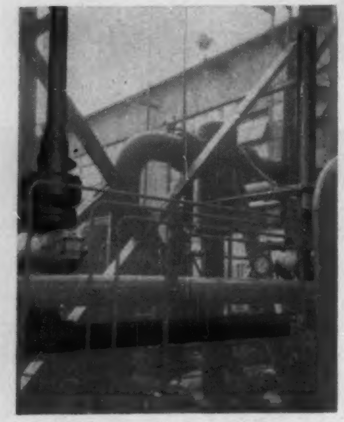
Neither prospect was pleasant. The plant had started up just as its full output was needed for the rush season.

▶**The Way Opens**—While studying this problem, Grace engineers L. C. Skinner and L. E. Lundahl recalled reading about the use of Stopples by pipeline operators. They decided to investigate the possibility of applying Stopples to their problem.

As a result of this study Skinner and Lundahl, with the assistance of Williamson representatives, planned and executed the following procedure:

1. Welded on 6-in. split tees with Lock-O-Ring flanges at Positions A and D, and mounted 6-in. full-opening gate valves (see diagram at left for positions, p. 290 for mechanical details).
2. Welded on 4-in. Thread-O-Ring nipples at Positions B and E, and mounted 4-in. full-opening gate valves.
3. Tapped Positions B and E with tapping machine and installed 4-in. bypass line. In this operation the tapping machine is mounted on the closed gate valve, the valve is opened for the actual tapping step, the tapping tool is then withdrawn into the machine and the gate valve closed. The tap is thereby made with the line under pressure and in normal service.
4. Tapped 1-in. vent at Position C with tapping machine.
5. Tapped Positions A and D and inserted 6-in. Stopples through the tapped openings into the main line. The Stopples, when seated in the line, cut off flow through the line.
6. Opened bypass from B to E, seated Stopples and opened vent at C.
7. Cut out section of 6-in. line between the Stopples and installed permanent piping to a new gas separator.
8. Pressurized new piping and withdrew Stopples, thus putting separator on stream.
9. Closed bypass valves and salvaged bypass piping.
10. Inserted and seated Lock-O-Ring plugs at A and D and screwed plugs at B and E, using tapping machine to maintain uninterrupted operation.
11. Removed and salvaged valves from A, B, D and E, and blanked off the nozzles.

▶**Mission Accomplished** — A similar procedure was used for installation of a purification and drying train. With this system,



BYPASS around main piping permits installation of new separator.

it was necessary to install a temporary bank of equipment in the bypass.

Only incident was failure of a Stopple to hold during test because of improper size of seal. This was easily corrected.

Grace completed these piping and equipment changes, tied it all in and removed all temporary valves without loss of production. Pressure in the system was maintained at more than 300 psi. during the entire operation.

Wyoming: Site of New Chemical Empire?

Feasibility studies of some $500 million worth of projects in Wyoming's Green River Basin—including chemical plants, a natural gas pipeline and a $200-million steam plant for power generation—have been started by two Wyoming firms. Rocky Mountain Corp., which owns or has under option more oil and gas leases in the basin than any other firm or individual, and Technical Industries Corp., its affiliate, are contemplating the development program.

The Rocky Mountain firm has already concluded studies which convince its officials that the basin holds one of the greatest reserves of natural gas in the continental U. S. Added inducement to develop the basin is Wyoming's liberal tax structure.

Technical Industries, an industrial development firm, has scheduled the following chemical projects for immediate study: Plants at the source of raw material and natural gas for the manufacture of butadiene rubber, anhydrous ammonia, carbon black, glycol and alcohol, petroleum detergents, plastics and other petrochemicals.

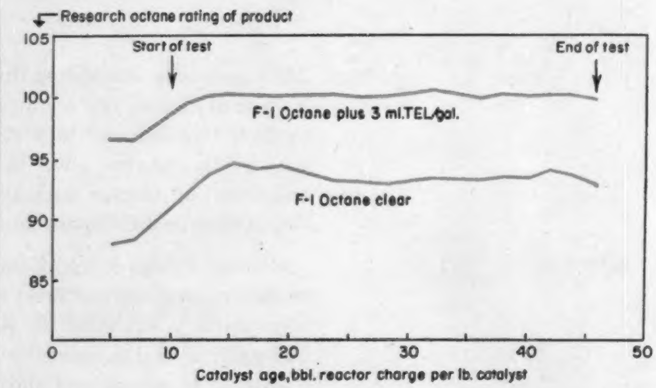
Cobalt Recovery Process Gets Pilot-Plant Try

Pilot-planting of the new Sill process for recovering cobalt from low-grade ores is due to get under way before year's end at 10-ton/day facilities in Newburgh, N. Y. Building the plant is Metallurgical Resources Inc., formed to handle the process, which was invented by Harley Sill, Los Angeles consulting metallurgical engineer.

Key step is a unique leaching operation, carried on in an autoclave under closely controlled conditions of temperature and pressure. Arsenic and sulfur impurities, which may run as high as 40 and 10% respectively, are made water-soluble and reduced to less than 2% total in the purified residue.

In that it involves leaching, the Sill process resembles Chemical Construction Corp.'s cobalt refining process now being used at plants of Howe Sound, National Lead and Sherritt Gordon. But Chemico's process and, in fact, all conventional ore-leaching processes used in metal refining put the desired metal values into solution. Metals are subsequently precipitated. In contrast, by solubilizing only the impurities, Sill enriches the ore residue. The process also differs from Chemico's in its use of an alkaline, rather than acid or ammonia, leaching medium.

Impurities in the ore residue are reduced to the point where the way is cleared for conventional recovery of the metal values. What's more, the arsenic and sulfur can be precipitated from solution in forms of value as byproducts, e.g., calcium arsenate, glauber salt.



No Catalyst Regeneration, No Sag in Octane Rating

Records of full-scale commercial tests, such as that above, show that 100-plus octane leaded Platformate can be consistently produced for prolonged periods without regenerating the catalyst. Results prompted Universal Oil Products (which conducted tests at refineries of Platforming-process licensees) to challenge seriously whether there is any economic justification for installing and operating regeneration facilities on a Platforming unit. Test runs, made over four to five months in units ranging from 1,500 to 11,000 bbl./day capacity, used a conventional platinum-containing catalyst.

For the 1st time!

META-XYLENE in commercial production

Have you considered the opportunities xylene isomer intermediates offer you for new or improved products? Or, perhaps a xylene isomer will provide you a better, more economical raw material as an alternative route in your present production.

Oronite was the pioneer and is today the leading producer of xylene isomers—the only source offering all three xylene isomers (meta, para, ortho) in commercial quantities. Inquiries are invited; trial quantities available. Contact the Oronite office nearest you for further information.

and

Oronite is your only commercial source for all 3 xylene isomers!

Typical tests of current production

		TYPICAL TESTS
META-XYLENE	Meta-Xylene, % (wt.)	95.1
	Boiling Range, °C (start to dry)	1.0
	Specific Gravity, 60°/60°F	0.869
	Color, Saybolt	+30
	Sulfur Compounds, as H_2S or SO_2	None
	Paraffins, %	0
PARA-XYLENE	Para-Xylene, % (wt.)	95.4
	Boiling Range, °C (start to dry)	1.0
	Specific Gravity, 60°/60°F	0.865
	Color, Saybolt	+30
	Sulfur Compounds, as H_2S or SO_2	None
	Paraffins, %	0.20
ORTHO-XYLENE	Ortho-Xylene, % (wt.)	86.3
	Boiling Range, °C (start to dry)	1.2
	Specific Gravity, 60°/60°F	0.875
	Color, Saybolt	+21
	Sulfur Compounds, as H_2S or SO_2	None
	Paraffins, %	8.0

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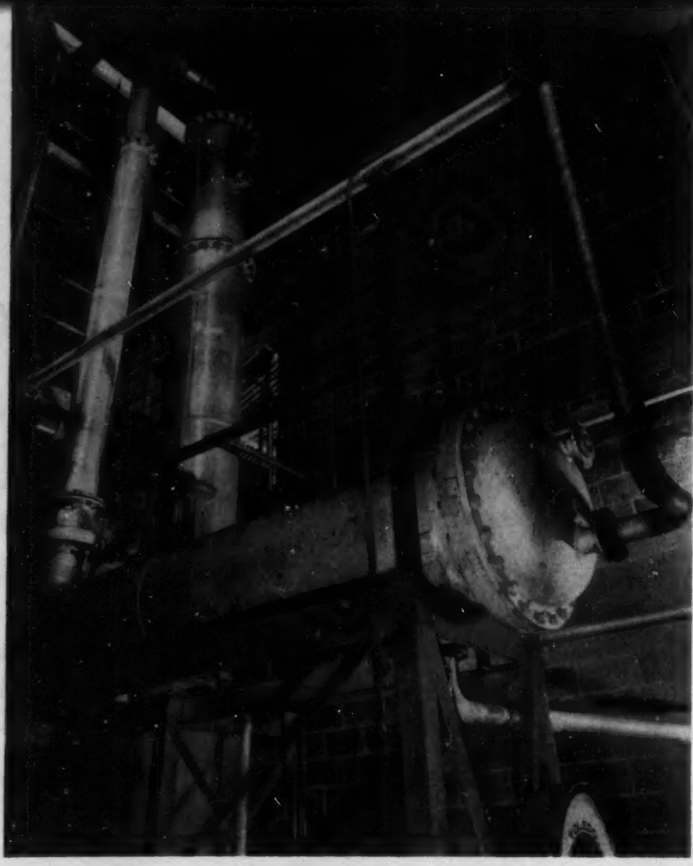


Now Continuous: Pine Gum Distillation

Automatically controlled, 30-ft.-high still cuts 1-hr. batch process time to 5 min.

First commercial U. S. plant for continuous distillation and refining of pine oleoresin has started operating in Trenton, N. J. Owned by Pine Chemicals, Inc., newly formed affiliate of Filtered Rosin Products, Inc., Baxley, Ga., the plant centers on a 30-ft.-high automatically controlled continuous steam still which affords the following advantages over batch stills:

- *Shorter process time*—In batch operation, gum must be held under high heat for as long as an hour. With continuous distillation, it passes through in five minutes.
- *Better product* — During long batch operation, the levopimaric acid in the gum isomerizes and tends to form abietic and intermediate acids. New still produces rosin more nearly in its natural state — more reactive, low in abietic acid, more color-stable.

Pine Chemicals' crude gum raw material comes from Filtered Rosin Products after initial filtering and washing. At Trenton it is again washed, chemically treated, then filtered under pressure. This removes dissolved and suspended impurities that form jelly-like material primarily responsible for variations in rosin quality and color.

Clean, preheated gum then passes into the new still. Heated to about 350 F., turpentine vaporizes, flashes off. Vapors are condensed and then passed through a separator, where caproic, valeric, isobutyric and butyric acids are removed.

High-quality hot rosin is drawn off the bottom of the still into large aluminum storage tanks, for packaging in drums and 100-lb. paper bags or for further processing. A large portion of the company's rosin production is earmarked for captive use in the manufacture of paper size and synthetic resins.

Oil Firm Streamlines Via Consolidations

Standard Oil Co. (Ind.) plans separate consolidations of three chemical, two producing, two pipeline and two refining and marketing subsidiaries by year's end. Object is to reduce duplication and overhead costs, though no reduction in employment is expected.

The consolidations: Indoil Chemical Co., Pan American Chemicals Corp. and Hidalgo Chemical Co. into a single company with a new name; Pan American Production Co. into Stanolind Oil and Gas Co.; American Oil Pipe Line Co. into Service Pipe Line Co.; and Pan-Am Southern Corp. into American Oil Co.

Another Vote For Inorganic Absorbents

For the second time in as many months comes announcement of a commercial installation which uses an inorganic absorbent for removal of carbon dioxide from synthesis gas. In contrast with more conventional use of organics (like monoethanolamine), Steinkohlengas A.G. at Dorsten, Germany, like Escambia Bay Chemical at Pensacola, Fla. (*Chem. Eng.*, Apr. 1956, p. 103), bases new scrubbing facilities on a potassium salt.

The German installation is at the firm's new 500-million-cu. m./yr. pressure-type gasification plant. Carbon dioxide contained in the raw gas is reduced from 30 to 2% by washing with hot potash lye.

At the Escambia Bay installation, an ammonia plant, hot 40% potassium carbonate solution cuts carbon dioxide in the hydrogen gas stream by 97-98%. There, and presumably in Germany, steam requirements for regeneration of the inorganic solution are substantially lower than those for monoethanolamine regeneration.

This, coupled with their substantially lower initial cost, would seem to predict continued growth for inorganic absorbents in this market.

Plants Look Better, Workers See Better

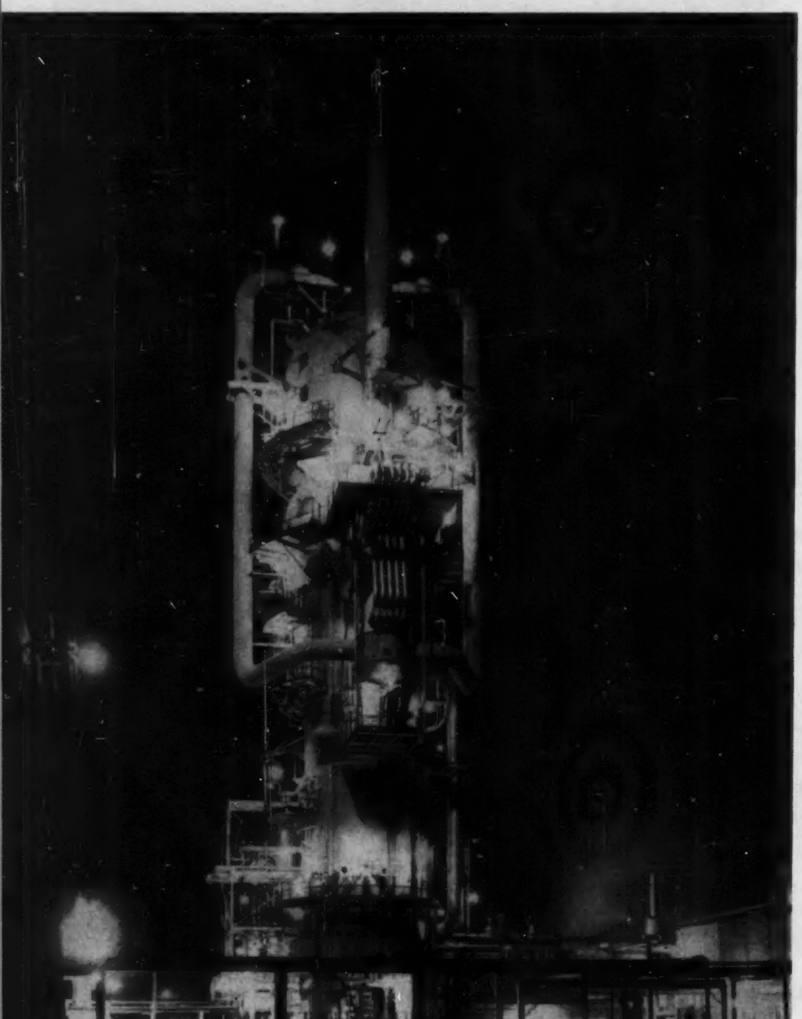
Modern lighting brightens today's chemical process plants. Hazardous areas, control rooms, outdoor structures require careful design to get best results.

WHAT you see in the photograph below is a good example of how modern engineered lighting is applied in chemical process plants. It's a nighttime view of a new unit in Pure Oil's petroleum refinery at Newark, Ohio.

The unit was designed by M. W. Kellogg Co., with lighting under the direction of E. C. Benjamin, head of Kellogg's electrical division.

As Benjamin points out, good lighting design today aims for more than merely giving the plant operator enough light to do his job. Just as important are these other objectives:

- Keeping intruders off plant property.
- Bringing fires quickly under control.
- Preventing accidental injury and property damage.
- Saving on maintenance costs.
- Boosting the morale of the operator and mechanic—who feel a whole lot better about their jobs if they can see what they're doing.



▸Fit the Location—The way you achieve these objectives, Benjamin says, is this: First, make each fixture powerful enough to give adequate light. Then fit each one carefully to its particular location. It's in this latter area that greatest progress is being made today.

Toughest item on the agenda is safe lighting for hazardous areas. Equipment for Class I, Groups C and D (areas inhabited by vapors of ethylene, gasoline, etc.) has been generally available for some time.

Now you can install complete explosion-proof lighting in the more dangerous acetylene and hydrogen-containing areas (Class I, Groups A and B). Crouse-Hinds has announced the availability of all necessary components, including switches, fixture hangers, seals, unions and condulet.

It's claimed that no special installation or maintenance operations are involved; whereas older models had to be removed to an nonhazardous area for relamping, this model can be taken care of on the spot.

If you prefer, you can now get fluorescent fixtures for hazardous areas, as well as the incandescent. Fluorescents give more light for the same amount of juice. And, some say, they have another advantage as well—that, designwise, they are more attractive.

▸Show Room — The trend — which has accelerated in recent years—to pay closer attention to aesthetics in plant design, demands a different type of special considerations for other indoor areas.

Because of the relatively unglamourous appearance of most plants and refineries, engineers now treat control rooms and instrument panels as the showplace of the firm. These areas lend themselves easily to modern

ammonia

1,035 tons/day from seven FW plants

This Tonnage capacity is a measure of *experience* that can be a valued asset to prospective ammonia producers anywhere in the world.

Seven modern synthesis plants, completed or under construction by Foster Wheeler — total capacity, 1035 tons of anhydrous ammonia per day!

Foster Wheeler's specialized know-how embraces all phases of process and equipment design, fabrication and erection. For complete information, write for Bulletin 0-54-1. *Foster Wheeler Corporation, 165 Broadway, New York 6, N.Y.*

Designed and engineered by our Paris office, this ammonia plant at Cubatao, Brazil, is being erected by 100 per cent Brazilian labor. It is a typical example of the flexibility and world-wide coverage of Foster Wheeler's engineering and construction services.

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RECESSED fixtures in control room ceiling give pleasing effect.

design. And a bit of care in designing lighting effects greatly enhances the attractiveness of the finished product.

Benjamin says that there's no problem in trying to conceal most of the wiring and other paraphernalia that go along with industrial lighting fixtures. These can be concealed in a hung ceiling.

Such recessed fixtures — or troffers—allow you to mount a variety of lighting fixtures flush in the ceiling without detracting from a uniform design. A hung ceiling lets you place regular fluorescents or incandescents in the ceiling above desk locations, while slanted reflectors, along the side of the control room, direct light to the vertical instrument panels. Mixing vapor-proof and regular nonexplosion-proof fixtures presents no problem, either, since their sizes match.

▶ **Outdoor Setup** — Certain peculiar lighting problems, posed by today's outdoor plant structure, are being met in a variety of ways.

If you were to summarize the problems in a general statement they add up to this: You've got to light the plant exterior for a 24-hour schedule. After dark, you can rely on floodlighting for a major portion of the job. Set 30-35 ft. off the ground on various tall structures, floodlights illumine wide areas.

But the problem doesn't stand solved at this stage. At a considerable height, less glare, contamination and corrosion are likely to result; yet, at this height, lighting effects are often hampered by fog and long, unwanted shadows.

To offset the latter drawback, engineers now do a better job on local lighting. They find luminaires an essential supplement (100-150-watt fixtures) at vital points, such as ladders and walkways.

▶ **Guard Against Failure**—They see, too, that automatic emergency lighting units are installed at strategic points. In case of an over-all power failure, these battery-powered units take over while repairs are made.

Some automatic units contain no manual controls whatever, are powered by trickle chargers. Thus the guess factor, which might result in overcharging or undercharging the battery, is eliminated.

One of these models is hermetically sealed against dust, vapors and water; another is explosion-proof.

▶ **Vapor Headaches** — Corrosive atmospheres which inhabit many chemical plants, because of either the nature of the operations or geographic location, play havoc with the life of some materials. These conditions dictate certain requirements in the actual makeup of lighting equipment. Engineers are now more careful to see that all components—reflectors, wiring plugs and sockets, in addition to the main fixture body itself—are corrosion resistant.

To stand up against such atmospheres Benjamin notes that bronze is a sturdy challenger, but that marketwise, it's not too popular because of the expense involved. Expense need not be a problem, though; these days galvanized fittings are only moderately more expensive (8-10%) than most unprotected materials and quite effective.

▶ **Trim Maintenance Costs** — Better planning for maintenance of good lighting pays off, say big manufacturers of lighting fixtures. For indoor areas, so far, they are pushing group lamp replacement plans over one-at-a-time methods.

Lower cost is the biggest selling point. Figures show that single lamp replacements run up labor costs. Over a period of time it costs less if the maintenance crew replaces all the lamps in one area at once.

Sylvania cites one recent instance where 11,000 lamps are replaced every two years at a cost of $0.53 per lamp instead of $1.08, the cost of individual replacement. This way, the company saves over $3,000 annually.

Better light is the other factor in favor. Latest tests show that by getting rid of lamps just before their last hours of life, you cheat them out of using the same electricity to produce progressively less light. Then, too, you get far more uniform illumination.

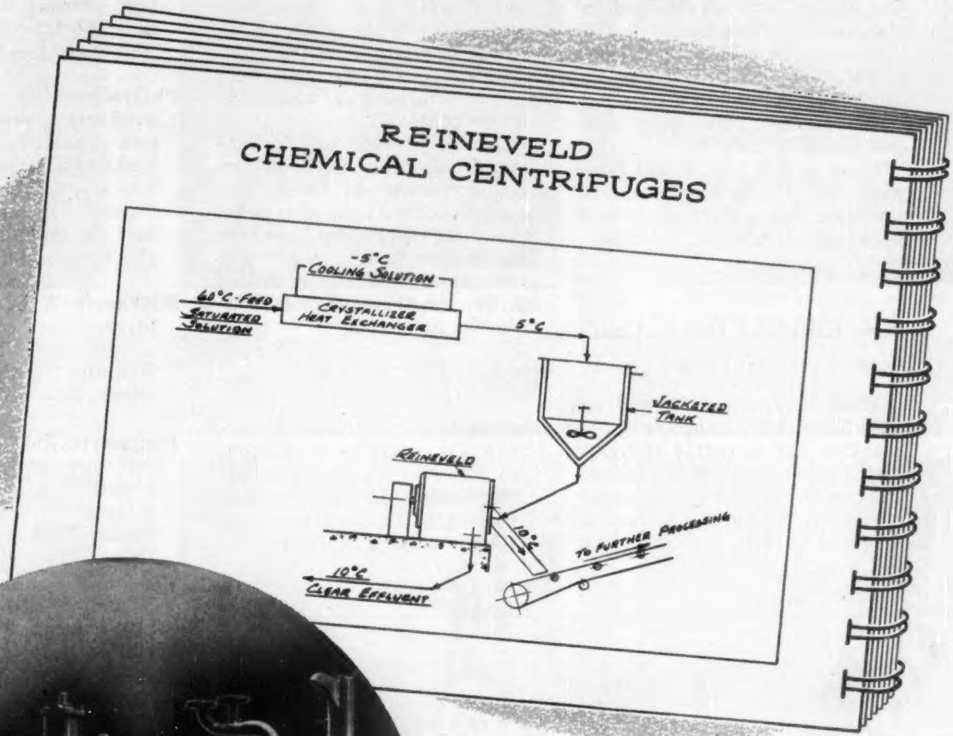
Engineers at Kellogg predict a brighter future for firms which invest in better lighting. Brighter, that is, in terms of fewer production halts, lower operating costs and a lot less strain on personnel.

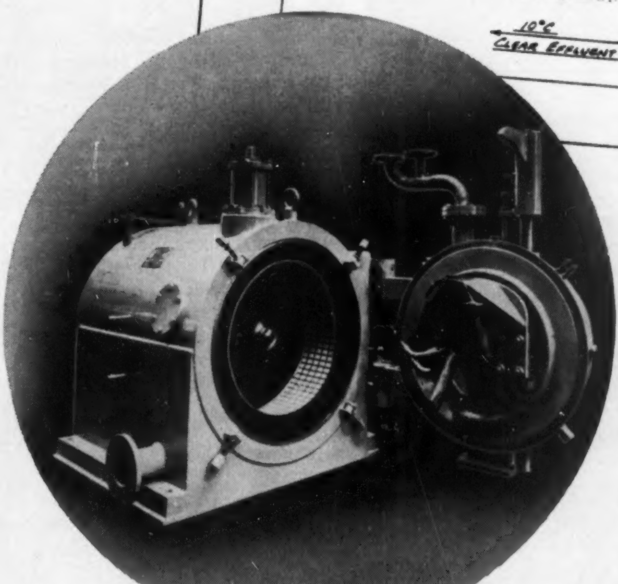
Hidalgo Plant Finally Starts Up

Here at last: Long-awaited startup of Hidalgo Chemical Co.'s Fischer-Tropsch plant in Brownsville, Tex. The plant, now completely rehabilitated, has stood idle since June 1953 when former owner, Carthage Hydrocol, ceased operations because of functional difficulties.

Critical phase of Hidalgo's modified Fischer-Tropsch process involves exposure of synthesis gas to an iron catalyst for conversion to two basic product streams—one comprised of chemicals, the other of liquid fuels. The synthesis plant is expected to require ultimately some 90

Out of the Engineer's Workbook...





The circuit illustrated above utilizes a Reineveld 28" Centrifuge, replacing three vertical machines formerly used in the process.

Man power requirements are reduced from 8 hours per shift to only one occasional visual inspection. This is made possible by Reineveld's completely automatic cycle of operation.

This centrifuge is fed, washed and discharged at full operating speed. It is jacketed to prevent heat loss and vented to remove toxic fumes.

For complete details, consult with a Heyl & Patterson sales engineer.

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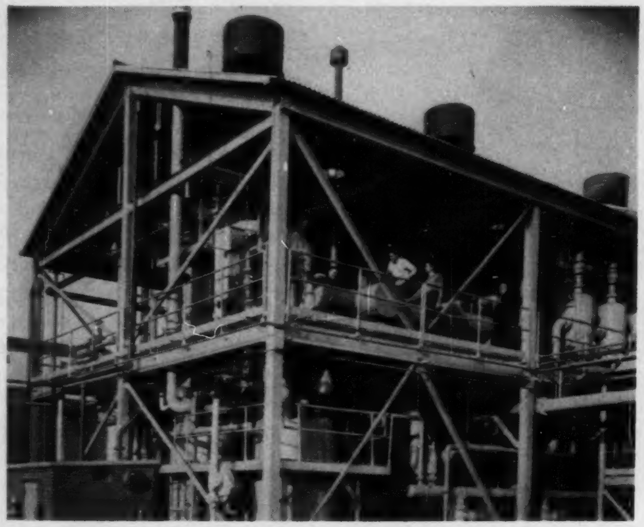
million cu. ft./day of natural gas, to be supplied from fields in South Texas. Oxygen, other starting material, will come from the largest unit of its kind in the country. With a total design capacity of 50 million cu. ft./day of 95% oxygen, it has almost as much as the combined capacity of all existing high-purity oxygen plants in the U. S.

Close to $50 million had been sunk into the original plant, a probable $45 million has been spent on the recent modifications.

New Ethylene Oxide Unit Caps Process Trend

With a proposed $8-million, 60-million lb./yr. ethylene oxide plant to use Scientific Design's direct oxidation process, General Aniline & Film joins such manufacturers as Allied Chemical & Dye and Carbide & Carbon in a three-year-old trend away from the chlorhydrin process. When all announced new plant construction (*Chem. Eng.*, Apr. 1956, p. 128) is completed, production of ethylene oxide by direct processes will exceed 750 million lb./yr.; existing chlorhydrin facilities yield about 550 million lb./yr.

Location of the plant in Linden, N. J., puts GAF in yet another parade—of those, like Koppers Co. with an announced 30-million-lb./yr. low-pressure polyethylene plant, who will draw raw material from Esso's ethylene recovery unit under construction in Linden.



Tetrahydrofurfuryl Alcohol Made a New Way

New Quaker Oats plant in Memphis for producing tetrahydrofurfuryl alcohol makes first use of a company-developed low-pressure catalytic hydrogenation process. Plant's output has already enabled Quaker to reduce the 43¢/lb. price of the distilled alcohol by 6½¢. Compound is used in the manufacture of lysine (an essential amino acid), in plasticizers, herbicides, solvents and a wide range of coatings.

News Briefs

Carbon black: Columbian Carbon Co. plans a 20-million-lb./yr. expansion for its Northbend, La., plant. And in conjunction with Celanese, it will build a 30-million-lb./yr. furnace-type carbon black plant near Santos, Brazil.

Atomic energy: AEC's $800-million gaseous diffusion plant near Portsmouth, Ohio, has been placed in full operation.

Phosphates: Westvaco Mineral Products is doubling production capacity for sodium and potassium phosphates at its Newark, Calif., plant. Victor Chemical plans to build a potassium polyphosphate plant at Chicago Heights, Ill.

Methanol: A $2-million plant to produce 7 million gal./yr. of methanol will be built by Hercules Powder Co. at Louisiana, Mo.

Pentaerythritol: Heyden Chemical Corp. has begun building a new 25-million-lb./yr. pentaerythritol plant at Heyden Fords, N. J.

Thorium: Metal Hydrides Inc. is underwriting a research program at Battelle Memorial Institute aimed at developing processes for producing tonnage amounts of thorium. Davison Chemical and Rare Earths, Inc., W. R. Grace subsidiaries, have joined in a program of expanded production, sales, research and development of rare earths and thorium.

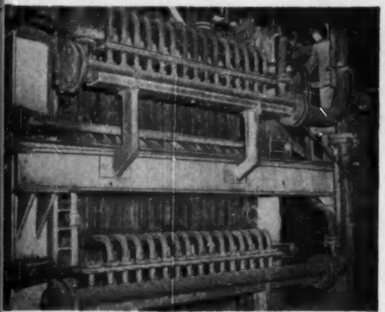
Formaldehyde: Plans for expansion in formaldehyde capacity at Spencer Chemical Co.'s Chicago works have been announced.

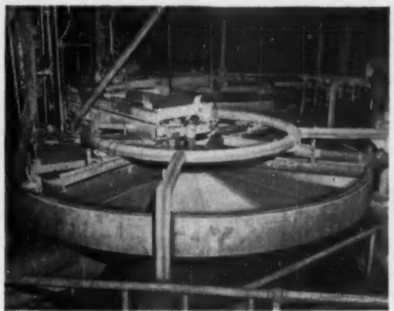
Sodium chlorate: Electric Reduction Co. will erect a $5-million sodium chlorate plant in Vancouver adjacent to Hooker Chemical's chlorine-caustic plant.

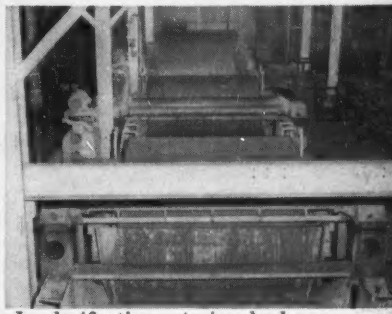
Rubber: American Synthetic Rubber Corp. plans to increase capacity of its copolymer plant at Louisville, Ky., by 50%. To be completed early in 1957, the expansion will bring output to 68,000 tons/yr.

For more of What's Happening, see FIRMS IN THE NEWS. 341

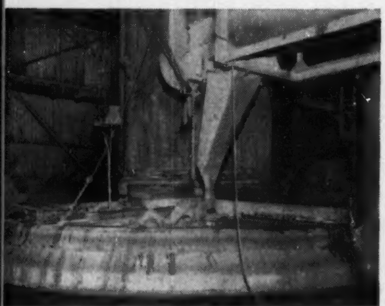
"We rely on lead at every stage of acid handling" says large chemical processor

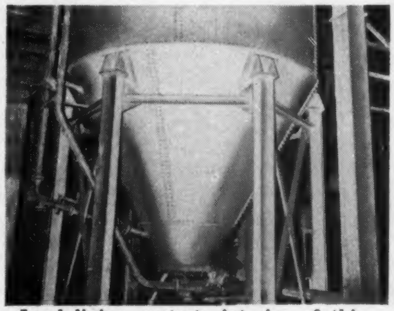

In this leaf filter, manifold and plates are lead

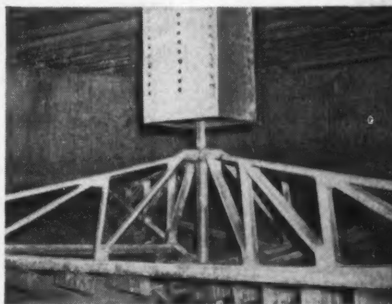

In horizontal filter, rim and concrete supports are lead-covered


In clarification rotaries, lead protects parts exposed to acid

"...in our filters

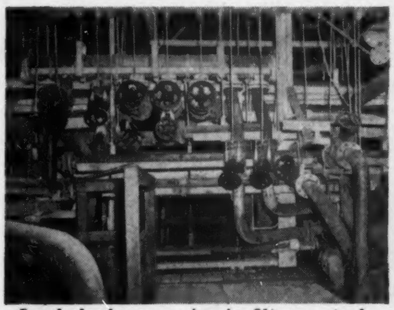

Lead apron 24" high guards digester rim against spill

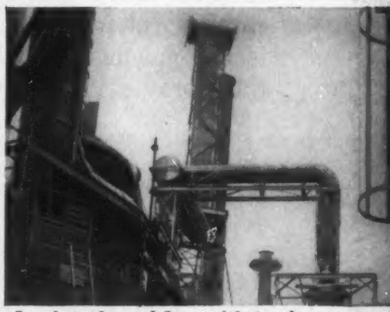

Lead lining protects interior of this steel digest tank


Lead lines this concrete settling tank, covers rake. Plows are solid lead

"...in our tanks


Lead-lined valves and piping serve digesters


Lead checks corrosion in filter control valve station


Lead stacks and flues withstand corrosive fumes.

"...in our lines...valves and pumps...and flues"

Lead's cost is low...its maintenance economical...its salvage value high

National Lead is a leading supplier of lead equipment for handling sulphuric acid solutions. If you have an acid control problem, we will be glad to help you solve it.

National Lead Company
111 Broadway, New York 6, New York

Swenson Spray Dryer used for drying silicagel catalyst.

EDITED BY R. K. GITLIN

Some of 1955's Major Installations

Company	Location	Use	Heater Btu. Hr.	Heater Fuel
American Cyanamid	Warners, N. J.	Chemical processing	500,000	Electric
Argus Chemical Corp.	Brooklyn, N. Y.	PVC stabilizers	3,000,000	Gas
Arnold Hoffman	Dighton, Mass.	Dye manufacture	1,600,000	Oil
Bendix Aviation	Troy, N. Y.	Phenolic resins	3,000,000	Oil
Celanese Corp.	Newark, N. J.	Chemical processing	250,000	Gas
Clinton Foods	Clinton, Iowa	Food processing	2,000,000	Gas-oil
Colgate-Palmolive	Jersey City, N. J.	Saponification	1,600,000	Gas
Cramet Inc.	Chattanooga, Tenn.	Titanium processing	8,000,000	Gas
Crawford Mfg.	Richmond, Va.	Vinyl coating	1,600,000	Gas
Curtis-Wright Aeronautical Co.	Woodbridge, N. J.	Jet fuel dehydration	1,600,000	Oil
Dow Corning	Midland, Mich.	Silicone manufacture	500,000	Gas
			250,000	Gas
Garlock Packing	Palmyra, N. Y.	Packing manufacture	500,000	Gas
Glidden	Chicago, Ill.	Alkyd resin manufacture	2,000,000	Gas
Hooker Electrochemical	Niagara Falls, N. Y.	Chemical processing	....	Gas and electric
	Montague, Mich.	Chemical processing	....	
H. W. Lay Co.	Jacksonville, Fla.	Potato chip manufacture	4,000,000	Gas
	Atlanta, Ga.	Potato chip manufacture	8,000,000	Gas
Monsanto Chemical Co.	Anniston, Ala.	Chemical processing	Small portable	
	St. Louis, Mo.	Chemical processing	up to 1,000,000	Gas and electric
	Monsanto, Ill.	Chemical processing		
	Montreal	Chemical processing		
Northrup Aircraft	Los Angeles, Calif.	Titanium sponge	2,000,000	Gas-oil
Pacific Dry Dock Co.	Oakland, Calif.	Heating asphalt barges	To 1,000,000	Oil or coal
Pennsylvania Industrial Chemical	Clairton, Pa.	Resin manufacture	....	Gas
Proctor Chemical	Salisbury, N. C.	Chemical processing	....	Gas
River Plate (Di Tella)	Newark, N. J.	Wax processing	650,000	Gas
Rohr Aircraft	Los Angeles, Calif.	Titanium sponge	1,000,000	Gas
Southbridge Finishing	Southbridge, Mass.	Vinyl calendering	3,000,000	Oil
			5,000,000	Oil
Standard Ultramarine Color	Huntington, W. Va.	Pigment and dye	750,000	Gas
Sterling Drug (Hilton Davis)	Cincinnati, Ohio	Drug manufacture	500,000	Gas
Thompson Products	Cleveland, Ohio	Sealer processing	4,000,000	Gas
Trubek Labs	E. Rutherford, N. J.	Organics distillation	200,000	Tantalum Bayonet Electric

More Markets for Unique Heating Medium

Fire resistance, noncorrosiveness and use at low pressure are the keys to chlorinated biphenyl's growing success in forced circulation, high-temperature heating.

For over a decade, a family of chlorinated polyphenyls, Aroclors, has made a name for itself in a number of widely different industrial applications—electrical insulation, nonflammable hydraulic media, high-temperature and high-pressure lubricants, expansion media, adhesives, plastics, pigments, paints, varnishes.

What has won a prominent place for these chlorinated organics? Their unusual properties, including nonflammability, noncorrosiveness, high resistivity and dielectric strength, low power factor, solubility in most common organics and drying oils, resistance to acids and alkalis.

▶ **Most Popular**—Of all the Aroclors now on the market, perhaps the one receiving the most attention is 1248, chlorinated

Newsworthy chemicals this month

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biphenyl, used as a heat transfer medium. Since 1941 the list of Aroclor installations has grown steadily. And in 1955 alone, a partial list of major installations (p. 142) totaled 34.

The rise in 1248's popularity has been due, in large measure, to a combination of two factors—a growing realization, on the part of design engineers, of the benefits of liquid-phase, high-temperature heating and 1248's unique properties which make it ideally suited for such operations:

- Fire resistant—Won't support combustion up to its boiling range of 652-725 F.
- Operates at low pressures—Not over 30 psig.
- Has good heat transfer properties—Efficient up to a maximum temperature of 600 F.
- Stable indefinitely at temperatures to 600 F. — When proper circulation is provided to prevent localized overheating.
- Noncorrosive to metals—Provided that the heater and piping are kept full of liquid at all points (to eliminate spaces where moist air might collect during shutdown).

Thus in forced circulation heating to 600 F., Aroclor 1248 reduces fire hazards; doesn't require costly high-pressure equipment; provides efficient, uniform heating.

▶**Simple Compact Heaters** — The Aroclor picture is not complete, however, without a brief mention of the equipment used in conjunction with it. Heaters (supplied by a number of leading manufacturers) are designed to meet requirements of specific processes, e.g., drug, resin, food processing.

They range from small portable units (usually electrically heated) to gas or oil-fired units with capacities from 250,000 to as high as 10,000,000 Btu./hr.

Low-cost, non-pressurized recirculating heaters are compact and simple to install, operate and maintain. They require low fluid makeup, are used for heating as well as cooling. Accurate temperature control provides product uniformity.—**Monsanto Chemical Co., St. Louis 4, Mo.** **142A**

Polyethylenes

Highly crystalline resins from Du Pont; stiff, dense, low softening poly from Imperial Chemical.

- Du Pont: Alathon 34 and Alathon 37 are said to have higher crystallinity than that available in any resins now on the market. 34 is designed specifically for film and bottles. Its greater clarity, stiffness, sparkle and high permeability make it particularly useful in film applications—soft goods packaging; coatings for paper, foil, etc. Stiffness plus resistance to heat distortion make it suitable for bottles and containers. Alathon 37 is a high-flow poly for general-purpose molding. Potential applications: housewares, where fast cycle, high gloss and stiffness, resistance to heat distortion are required.

- Imperial Chemical: Alkathene HD is a modified Alkathene which is stiffer, denser and has a lower softening point. Geared for general purpose molding, it has these advantages: sterilization for 15 minutes at 110 C. without distortion; thinner wall sections (leading to weight savings); improved stiffness and finish; higher working pressures and temperatures for extruded pipe work; thinner insulation and tougher sheath for cabling; film less permeable to water vapor and gases, more resistant to oils and fats.—**E. I. du Pont de Nemours & Co., Wilmington 98, Del.; Imperial Chemical Industries, London, Eng.** **144A**

Cationic Surfactant

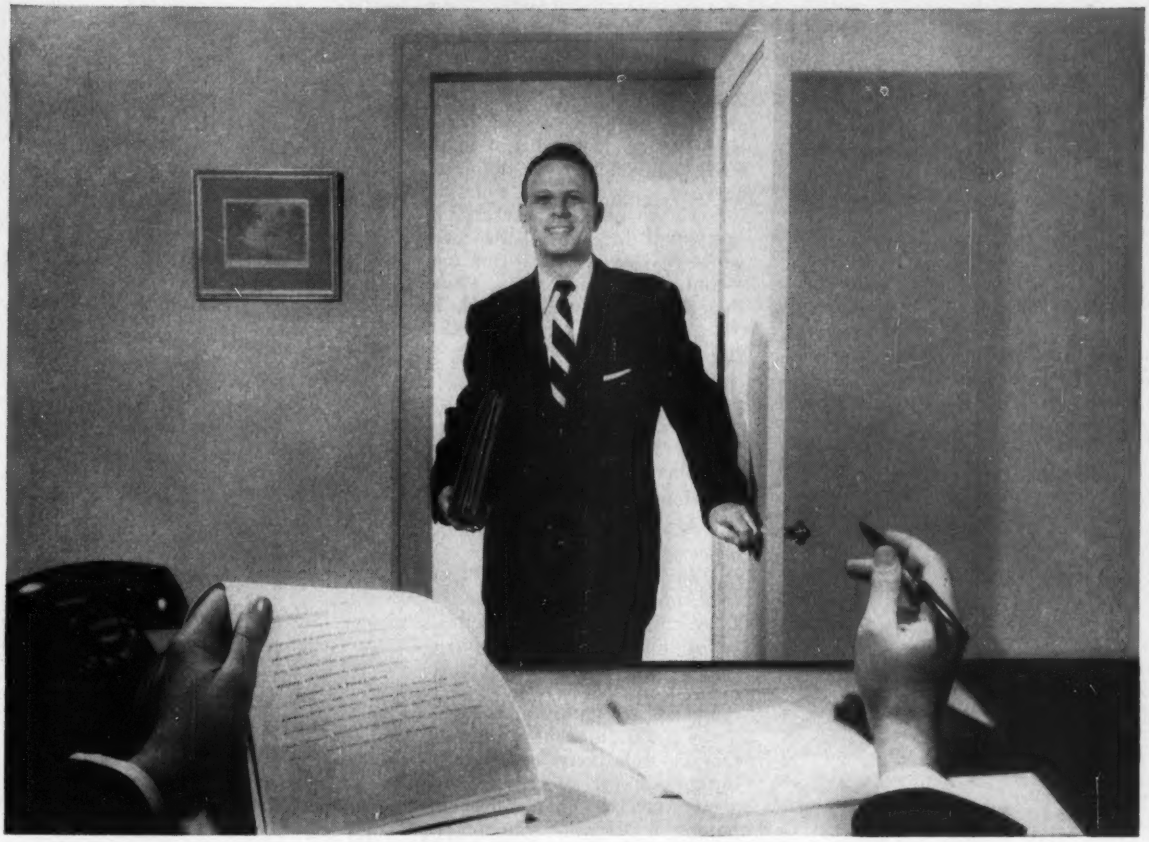
Causes instant dispersion of pentachlorophenol concentrates in water.

Thanks to a liquid cationic surfactant, pentachlorophenol (a herbicide, defoliant and soil toxicant) can be instantly emulsified in water.

For emulsifiable concentrates containing up to 15% pentachlorophenol, 1-5% surfactant,

For More Information...

about any item in this department, circle its code number on the Reader Service Postcard inside the back cover.



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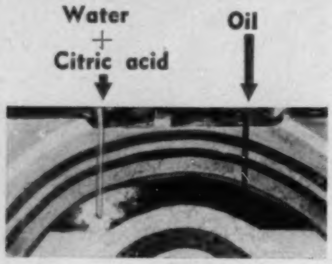
In Canada: Carbide Chemicals Company, Division of Union Carbide Canada Limited, Montreal.

Emulsifier 1990-A, is used. Preparation of concentrate consists of heating the mixture of pentachlorophenol and solvent to form a solution to which emulsifier is added.

The end user adds concentrate to water when he is ready to apply the chemical. And when Emulsifier 1990-A is added, the concentrate produces a flash dispersion in water without the need of mechanical agitation. The emulsion is stable in either hard or soft water. **— Market Development Dept., Chemical Div., Armour & Co., Chicago 9, Ill.** **144B**



Citric Acid's New Role

Prevents precipitation of insoluble iron salts in secondary oil recovery.

Versatile citric acid is now being put to work as a sequestrant to solve an important problem in the petroleum industry—costly iron plugging, a major cause of flow stoppage in secondary oil recovery.

When oil wells cease to produce or produce at a low, uneconomical rate, oil remaining in the reservoir is salvaged by secondary methods—either repressuring the reservoir with gas or air or, in many areas, pumping water into the producing formation. Effectiveness of the latter technique is, however, often diminished by insoluble iron compounds which plug the underground interface and lower water injection rates.

And this is where citric acid comes into play. Its ability to preferentially sequester iron, even in high calcium waters, prevents precipitation of insoluble iron salts. Thus the use of current methods like acidizing and fracturing can be eliminated and flow rate of oil can be boosted at less cost.

In addition, citric acid increases the efficiency of some bactericides which are ordinarily less effective in the presence of metallic ion, averting interaction between bactericide and metal ion. And it also prevents rust and scale formation. **— Chemical Sales Div., Chas. Pfizer & Co., Brooklyn 6, N. Y.** **146A**

Chlorofluorocarbons

Chemical intermediates for plastic, paint, refrigeration, textile fields.

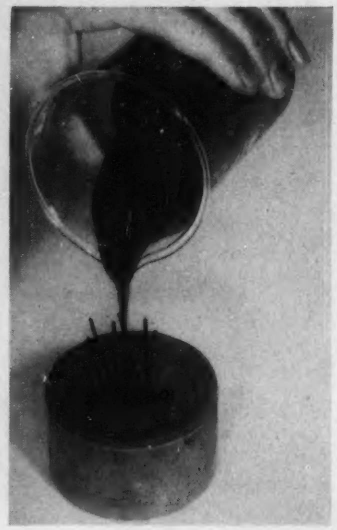
A wide variety of chemical processing industries are expected to reap benefits from four new chlorofluorocarbons—2, 3-dichlorohexafluorobutene-2; 1, 2-dichlorohexafluorocyclopentene-1; 2, 2, 3, 3-tetrachlorohexafluorobutane and 2, 2, 3-trichloroheptafluorobutane.

• 2, 3-Dichlorohexafluorobutene-2—Relatively reactive intermediate for preparing such compounds as chlorofluorocarbons, fluorinated monomers, chlorofluoro and perfluoro acids. These materials should find application in plastics, refrigeration, textile, paints and protective coatings.

• 1, 2-Dichlorohexafluorocyclopentene-1—Reactivity promoted by double bond makes possible the preparation of highly fluorinated compounds containing functional groups. Oxidation gives an intermediate for compounds such as acid halides, esters, alcohols, anhydrides. Markets: polyester and polyamide resins, hydraulic fluids, elastomers, wetting agents.

• 2, 2, 3, 3-Tetrachlorohexafluorobutane—Substitution of chlorine atoms by fluorine leads to a series of compounds with possible value as dielectrics, coolants, refrigerants. Material is solid under normal conditions and is of interest in protective coatings and as a fumigant.

• 2, 2, 3-Trichloroheptafluorobutane—Resists common oxidizing agents. Its thermodynamic and electrical properties suggest applications as a coolant, dielectric and refrigerant. **—Hooker Electrochemical Co., Niagara Falls, N. Y.** **146B**



Embedding Epoxies

Used in wide range of electrical and electronic insulation applications.

A new family of epoxy resins, tradenamed Randac, has been developed for a variety of applications including coating and encapsulating, corona control, sealing, cast embedding of electrical parts and electronic assemblies.

Three main types of Randac resins are R-4060, R-4059 and R-4053.

• R-4060 — A general-purpose, rigid type resin reinforced with low-loss inert fillers. Has excellent electrical properties at high temperatures, excellent moisture resistance, is completely corrosion proof and easy to handle. R-4060 cures in 3 to 6 hours to a rigid, stable state, remaining rigid at temperatures close to 300 F. It can be poured at room temperature or temperatures to 170 F., maintaining the fluid state for 2 to 3 days at room temperature and for several hours at 170 F.

• R-4059 — 100% reactive, mineral - filled, thermosetting liquid for room-temperature applications. Semiflexible in the cured state, it has relatively low viscosity, 2 to 4-day bath life. R-4059 is also resistant to moisture and thermal shock.

• R-4053—100% solid resin containing mineral filler. Has high dielectric strength, good

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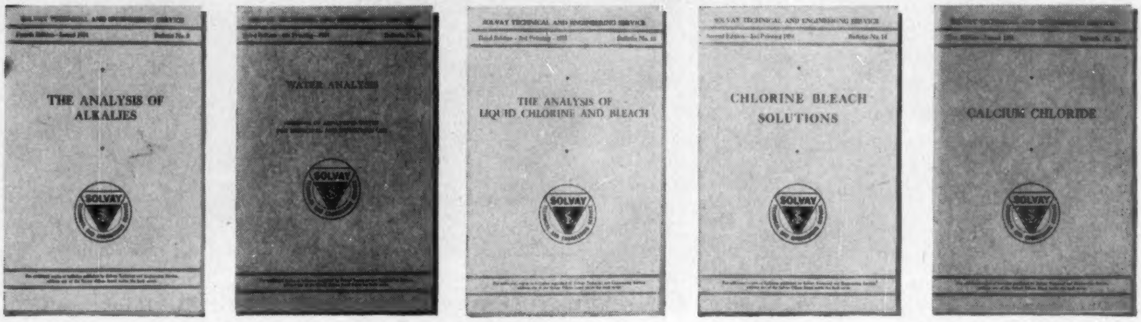

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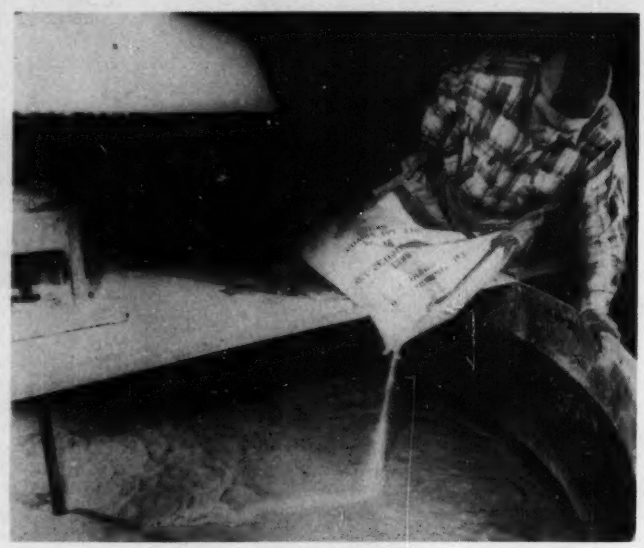
Methyl Chloride • Ortho-dichlorobenzene • Monochlorobenzene
Carbon Tetrachloride • Chloroform • Methylene Chloride
Hydrogen Peroxide

moisture resistance, excellent stability toward thermal shock. R-4053 is thermoplastic until cured, therefore can be molded without a mold, poured, used in dip-coating operations. — Mitchell-Rand Insulation Co., New York 7, N. Y. 146C



Coagulant Aid Simplifies Water Clarification

A new coagulant aid, a mixture of polyelectrolyte and bentonite clay, is saving time and money for Jones & Laughlin Steel Corp. in the tin plate department at its Aliquippa, Pa., plant.

Addition of the mixture to the department's water clarification and demineralization system makes the sludge blanket more stable and less sensitive to flow rates, produces a tough, rapid settling floc. It also saves J&L an estimated 30% in the amount of alum coagulant used. And reduced alum dosage in turn has cut the amount of alkali required for pH adjustment.

Other savings: reduction in regeneration chemical cost, fewer regeneration cycles in deionization (step following clarification); only 15% as much storage floor space required as compared with other, more bulky materials.—Hagan Corp., Pittsburgh, Pa. 148B

Silicone Rubbers

Two for fast one-step thick section curing, two for live steam resistance, two with 2x the tear and tensile strengths of conventional silicone rubber.

Activity in the silicone rubber field is continuing at a lively pace, witness the recent announcement of six new compounds—four from Carbide and Carbon, two from Connecticut Hard Rubber.

Carbide & Carbon's K-1025 and K-1028 are general purpose compounds which can be used for rapid, one-step thick section curing with the new catalyst, di-tertiary-butyl peroxide (DTBP). Time, trouble and expense can thus be eliminated in building up rubber rolls or making moldings and extrusions for industrial purposes. Both compounds have very low compression set (without need for toxic additives), important in making such items as heat- and cold-proof motor mounts, refrigerator door seals, kitchen oven door gaskets. And both meet or exceed Aeronautical Materials Specifications (AMS) and ASTM specs.

Two other Carbide silicone rubbers offering good live steam resistance and low moisture absorption are K-1035 and K-1038. Both compounds, suitable for general molding and extrusion, have very low compression set without need for toxic additives. Normally they are shipped uncatalyzed from the Tonawanda, N. Y., silicones plant to the fabricator so that he can select the catalyst best suited for individual applications. K-1035 and K-1038 may be catalyzed with benzoyl peroxide or ditertiary-butyl peroxide.

All four rubbers—1025, 1028, 1035 and 1038—come in neutral and red colors.

Connecticut Hard Rubber's latest Cohrlastic rubbers, HT-655 and HT-666, overcome major defects of conventional silicone rubbers—low tear strength and poor abrasion. HT-655, a methyl base material, is particularly designed for high-temperature work and will remain flexible at −65 F. At room temperature, its tear strength is 197 lb./in., tensile strength is 1,650 psi., elongation is 900%. Comparable figures for conventional silicone rubbers are 100 lb./in., 695 psi., 390%.

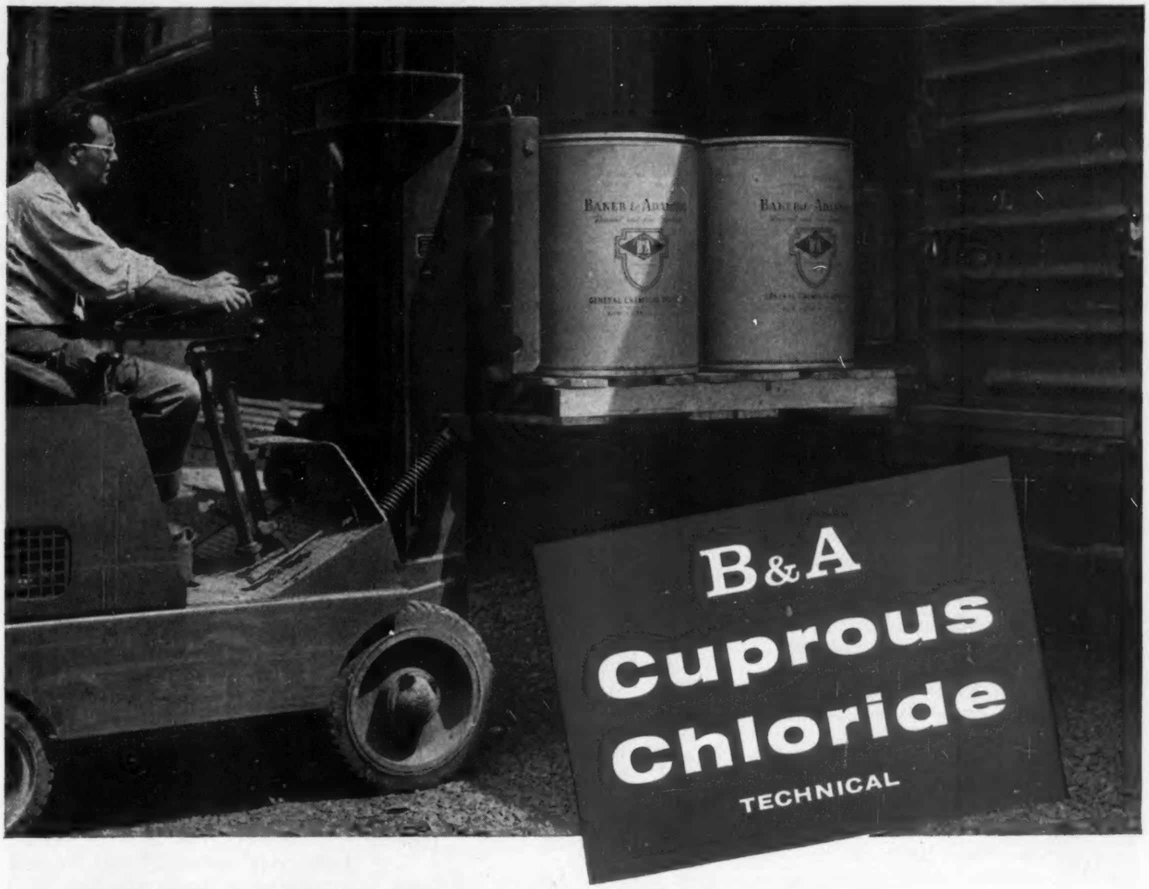
HT-666, a methyl phenyl base material, has original properties equal to or better than those of 655 in tear resistance, slightly lower in tensile strength and elongation. It has outstanding low-temperature flexibility at −100 F.—**Silicones Div., Union Carbide & Carbon Corp., New York 17, N. Y.; Connecticut Hard Rubber Co., New Haven 9, Conn.** 148A

Polystyrenes

Improved general purpose formulations and high impact materials.

Four new members have been added to the Styron (Dow polystyrene) family—two general purpose formulations with

PLUS ONE To Grow On



... Now available from 2 furnaces!

For Immediate Shipment in Any Quantities!

Baker & Adamson has long been industry's primary source of high-quality Cuprous Chloride. With its two large furnaces, B&A has geared its productive capacity to serve today's tonnage users as well as companies anticipating increased consumption in the future.

The specifications listed at the right show one big reason why B&A Cuprous Chloride is preferred. The other reason is ready availability.

For a source of Cuprous Chloride that you can rely on for any quantity . . . at any time, see B&A. Just phone or write your nearest B&A office now for samples, experimental quantities, data sheet and price information.

FINE CHEMICALS

REAGENTS

*Complete stocks carried here.

Specifications

Assay (CuCl)	95% min.
Insoluble in HCl	0.05% max.
Sulfate (SO_4)	0.01% max.
Iron (Fe)	0.015% max.

Screen Size:

Thru 20 mesh	100%

NOTE: A finer particle size of this product, approximately 100 mesh, is also available for use in the manufacture of special batteries, or for other purposes where a smaller particle size is required.

SUGGESTED USES

As a catalyst in the manufacture of acrylonitrile.

In the manufacture of vat dyestuffs.

In the manufacture of phthalocyanine pigments.

In the manufacture of special batteries (See note).

SHIPPING CONTAINERS

100-lb. and 350-lb. drums with polyethylene bag liners.

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improved flow and extrusion properties, two high impact materials with improved surface finish and heat resistance.

• General purpose formulations—Styron 665 and Styron 689. 665 is tailored for extrusion work (general shapes, bristles, thin film). It provides superior performance after the extrusion operation by a greater resistance to shattering or cracking when cut off to desired lengths. 689 is an easy flowing molding compound developed to meet the requirements for molding thin sections, deep draws and parts demanding accurate dimensional control. And it's well suited for high speed automatic molding operations and for large area parts.

• High impact compounds—Styron 440 and 429. 440 adds high heat resistance to high impact strength, excellent surface finish and good moldability. It retains high impact properties with a heat distortion over 200 F. This combination of properties should be useful in molding radio cabinets; automotive, refrigeration and photographic parts. 429 gives greatly improved surface finish and gloss to sheet products. Greater flexural strength should prove advantageous for economical vacuum forming of products from thin extruded sheet.—**Dow Chemical Co., Midland, Mich.** 148C

BRIEFS

Superfine zinc dust with an average particle size of 2-2½ microns and 95-97% metallic zinc content makes for good surface characteristics in zinc-rich paints. Applications: smooth surface primers, primers with improved suspension properties, high viscosity paints, paints with low weight per square foot. Gloss paints containing up to 50% Superfine Zinc Dust Pigment can also be produced. —**Pigment & Chemical Co. Ltd., Montreal, P. Q.** 150A

Non-hygroscopic sequestrant eliminates undesirable features of conventional drum or spray-dried product, e.g., caking during storage, picking up moisture on exposure to humid atmospheres. Product, Perma Kleer 80 Crystals, is a combination of pure Perma Kleer 80 with water of crystallization. But despite water content, concentration of active chelating agent is said to be higher than in any other form offered commercially. Crystals form stable chelates with all divalent and most trivalent metal ions.—**Refined Products Corp., Lyndhurst, N. J.** 150B

Gold-colored aluminum — sunfast and non-fading—is made by anodizing under readily controlled conditions. Patented process provides color source in the metal itself, eliminating uncertainties arising from the use of dyes or other coloring agents in the anodic coating. Gold color may be varied from pale straw to deeper gold and gold-bronze tones. Finish may be either bright or satin. Potential markets: automotive trim, home appliances. — **Kaiser Aluminum & Chemical Corp., Oakland, Calif.** 150C

Elemental boron in quantity lots is now being sold under a new, reduced price schedule: lots of 1-4 lb., $25/lb.; 5-24 lb., $20/lb.; 25-99 lb., $15/lb.; 100 lb. and over, $13/lb. Prices previously ranged from $25 in small lots down to $20 for larger quantities. All prices are for Trona Standard 90-92% elemental boron, f.o.b. Vernon, Los Angeles, or Trona, Calif. —**American Potash & Chemical Corp., Trona, Calif.** 150D

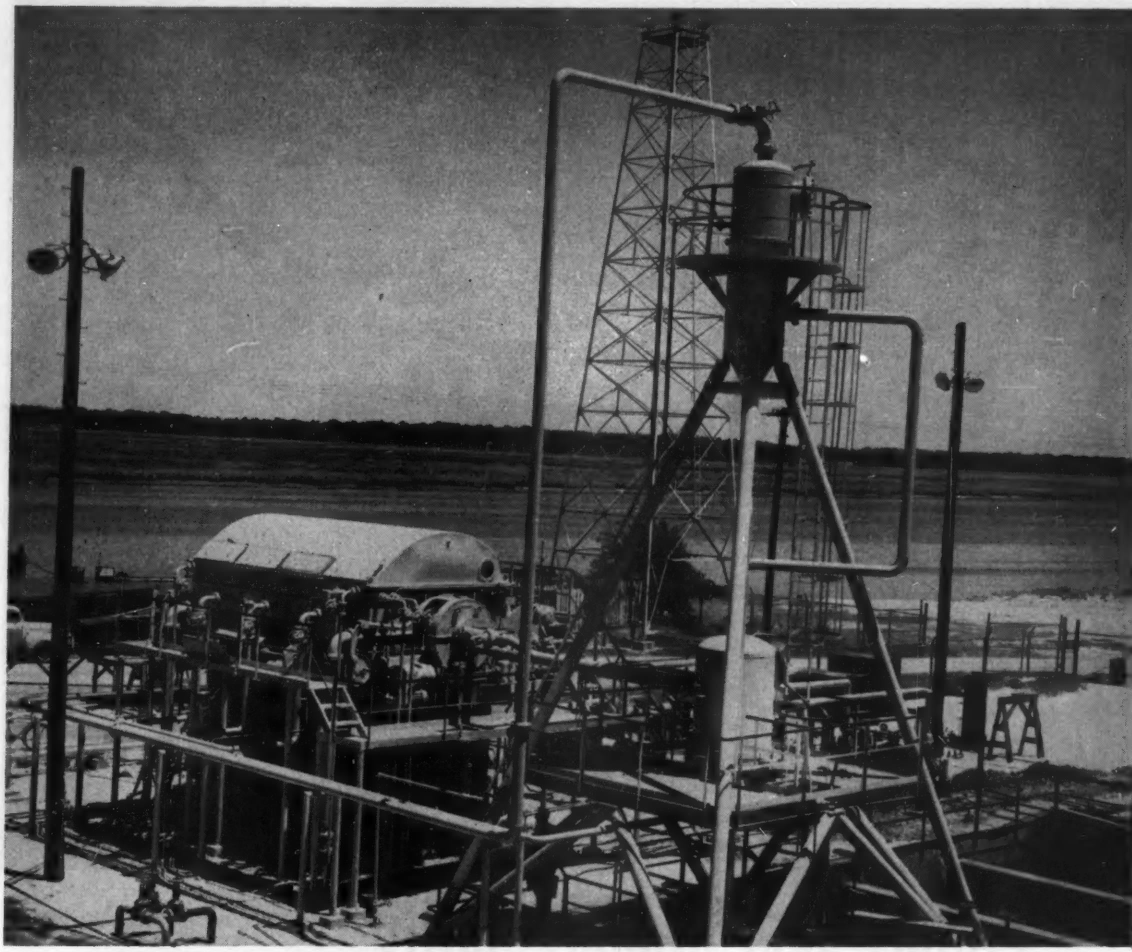
Four epoxy resins, members of a new series of epoxies for corrosion-resistant surface coatings, offer excellent adhesion and resistance to weather, salt spray, corrosive fumes and chemicals. Two of the resins, EKRA-2002 (solid) and EKSA-2002 (in solution), react with amines, polyamides, urea-formaldehydes resins. The other two, EKRD-2003 and EKRA-2053, though designed to esterify with vegetable oil acids, also undergo all the usual epoxy reactions.—**Bakelite Co., New York 16, N. Y.** 150E

Three new organic mercurial seed dressings are Puraseed, Gallotox and Gallotox-51. Puraseed is a combination of a special organic mercury compound and an organic cadmium compound. Synergistic action between the components increases the effectiveness and safety of the disinfectant. Puraseed is nonvolatile, can be used either as a slurry or dust. Gallotox is a non-volatile liquid; Gallotox-51 is a volatile liquid. —**Gallowhur Chemical Corp., Ossining, N. Y.** 150F

Sampler kit of rubber and elastomeric materials compounded, milled and calendered in ARco mills offers variety (11) of standard compounds used in corrosion and abrasion resistant lining work. Sampler is 3½ x 8½-in. folder. — **Automotive Rubber Co., Inc., Detroit 39, Mich.** 150G

Industrial solvent, Vinsol, is reputed to be as effective as carbon tetrachloride, but up to 20 times less toxic. Because Vinsol is nonflammable, it can be used for virtually all applications, including those in confined areas, near open flames, next to grinding equipment. Recommended uses: removing oil, grease, wax, tars from tools, sheet metal, etc.—**Speco, Inc., Cleveland, Ohio.** 150H

Germicidal, carnauba-type liquid floor wax contains all the desirable characteristics of a fine quality floor wax plus a potent germ-killing ingredient. The germ killer, *o*-benzyl-*p*-chlorophenol, is completely compatible with the wax and is nontoxic to humans and animals. Floors stay bacteria free as long as Amazon Germicidal Floor Wax remains on. And damp mopping actually increases germ-killing activity. — **Trio Chemical Works, Inc., Brooklyn, N. Y.** 150I




PRODUCT APPROVAL

4 EXCLUSIVE REASONS WHY...

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vented Explosion-Proof Fixtures are BETTER!

- **"FLAME-TIGHT" CONTACT CHAMBER**
  Exclusive safety chamber prevents explosions even when fixture is serviced with current on! APPLETON *Series AA-51 Vented Explosion-proof Fixtures* offer the positive protection required for hazardous areas.
- **"FULL-CIRCLE" VENTING**
  Porous metal interior and specially designed hood dissipate heat evenly and safely . . . keep fixture temperature down, provide longer lamp life.
- **"INTERCHANGEABLE" UNILET BODY**
  Standardized diameters at top of Dome Unit Assembly permit interchange with AA-51 fixtures of varying wattages.

plus conversion to different wattages or relamping in just *58 SECONDS!* . . . with no loss of man-hours or lengthy shut-downs. Send for complete information today!

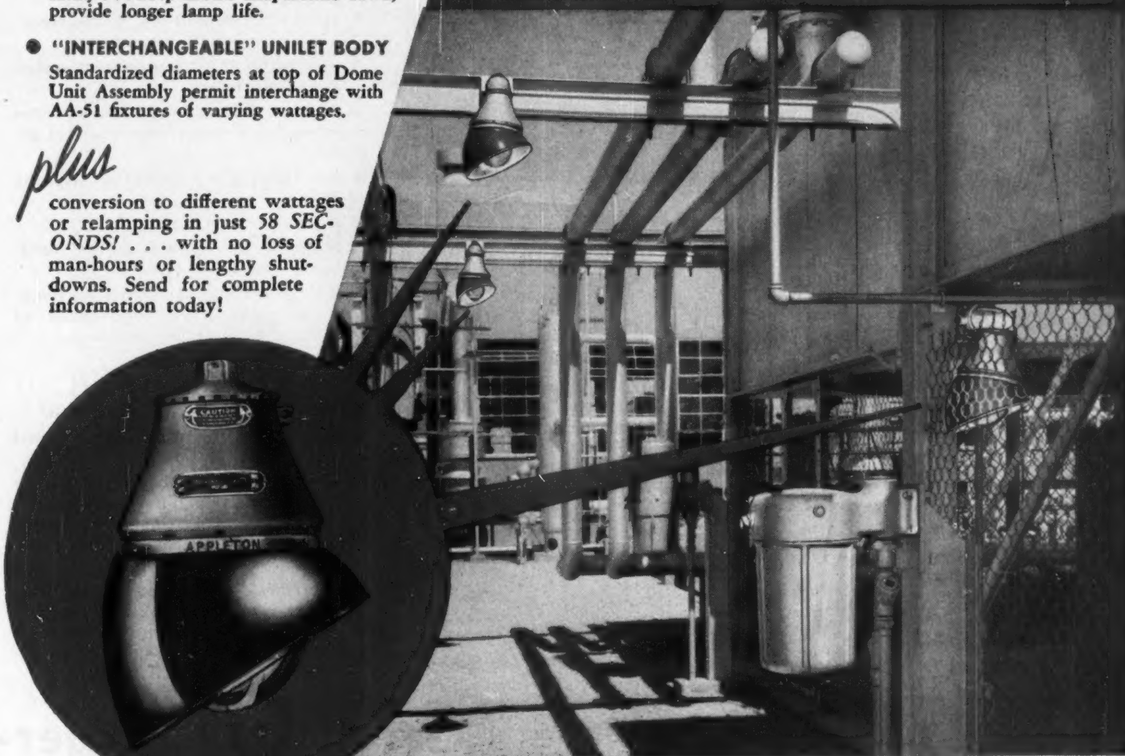
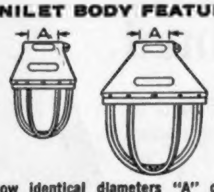


Photo Courtesy Oil and Gas Journal

APPLETON INTERCHANGEABLE UNILET BODY FEATURE



Note how identical diameters "A" on Dome Assemblies allow quick interchange of fixtures with different wattages.

58 SECOND RELAMPING

Series AA-51 stand-by units are ready at an instant's notice for relamping . . . with handles attached in advance.

Only a screw driver is needed to change units . . . and ONLY 58 SECONDS to climb ladder, change unit and descend!

Cleaning fixtures, changing burned out lamps can safely be attended to at bench . . . preventing costly shut-downs.

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Rely on **APPLETON** *. . . the standard for better wiring*

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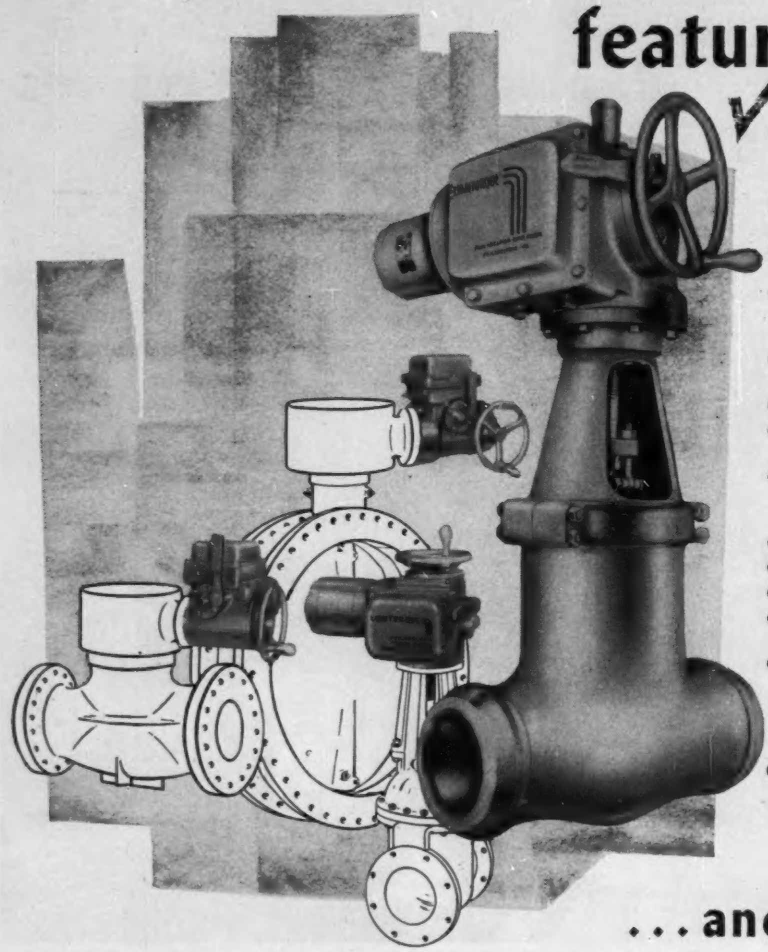

- Micrometer torque seating switch gives tight valve closure, and protects valve parts from damage.
- Self contained unit—no gears, stem nut or bearings to buy.
- Weatherproof, dust-tight and water-tight construction.
- Hammerblow device . . allows motor to reach full speed, before load is engaged.
- Non-rotating handwheel built into the unit.
- Automatic declutching.
- Motor is disengaged during handwheel operation.
- Can always be declutched for handwheel operation regardless of weather or electrical conditions.
- High torque motors.
- Simple valve yoke.
- May be mounted in any position.
- Three to four times faster handwheel operation.
- Actuation may be by any available power source such as electricity, air, oil, gas, water or steam. LimiTorque is readily adapted for microwave control.
- LimiTorque is designed for plug, butterfly, gate and globe valves up to 96" diameter . . . Entire Unit and nut can be lifted off valve yoke, by removing flange bolts.

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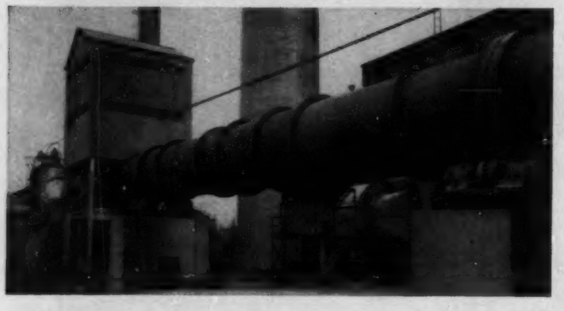

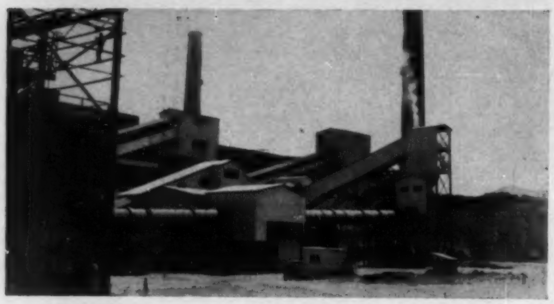

Throughout the chemical industry... wherever you find a sizeable thermo-processing operation... you'll find a Traylor Rotary Kiln on the job protecting product quality, reducing maintenance bills and lowering production costs.

Traylor's half-century of engineering experience has produced many major improvements that have become accepted standards for modern kiln design. Cast steel or forged steel riding rings, of the full-floating type are specially mounted to hold them securely in place relative to the easily adjustable single roller supports. The roller supports are of heavy integral design and can be adjusted as a unit. The shells are extra heavy with ample reinforcing bars. Thus, Traylor Kilns achieve exceptional thermo-processing and maintenance economies.

The success of Traylor Rotary Kiln design is best emphasized by the large number of leaders in the processing industries who have returned time after time to purchase additional Traylor Kilns.

Traylor has custom built Rotary Kilns in sizes to 12′ in diameter and 450′ in length. For full specifications on a kiln to best suit your specific product, write for a free copy of illustrated bulletin 1115 outlining the features of Traylor Rotary Kilns, Coolers and Dryers.

A Traylor LEADS TO GREATER PROFITS

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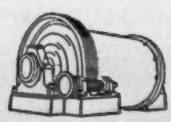
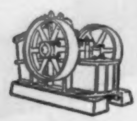
PRIMARY GYRATORY CRUSHERS

ROTARY KILNS

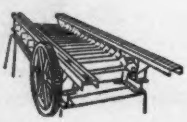
SECONDARY GYRATORY CRUSHERS



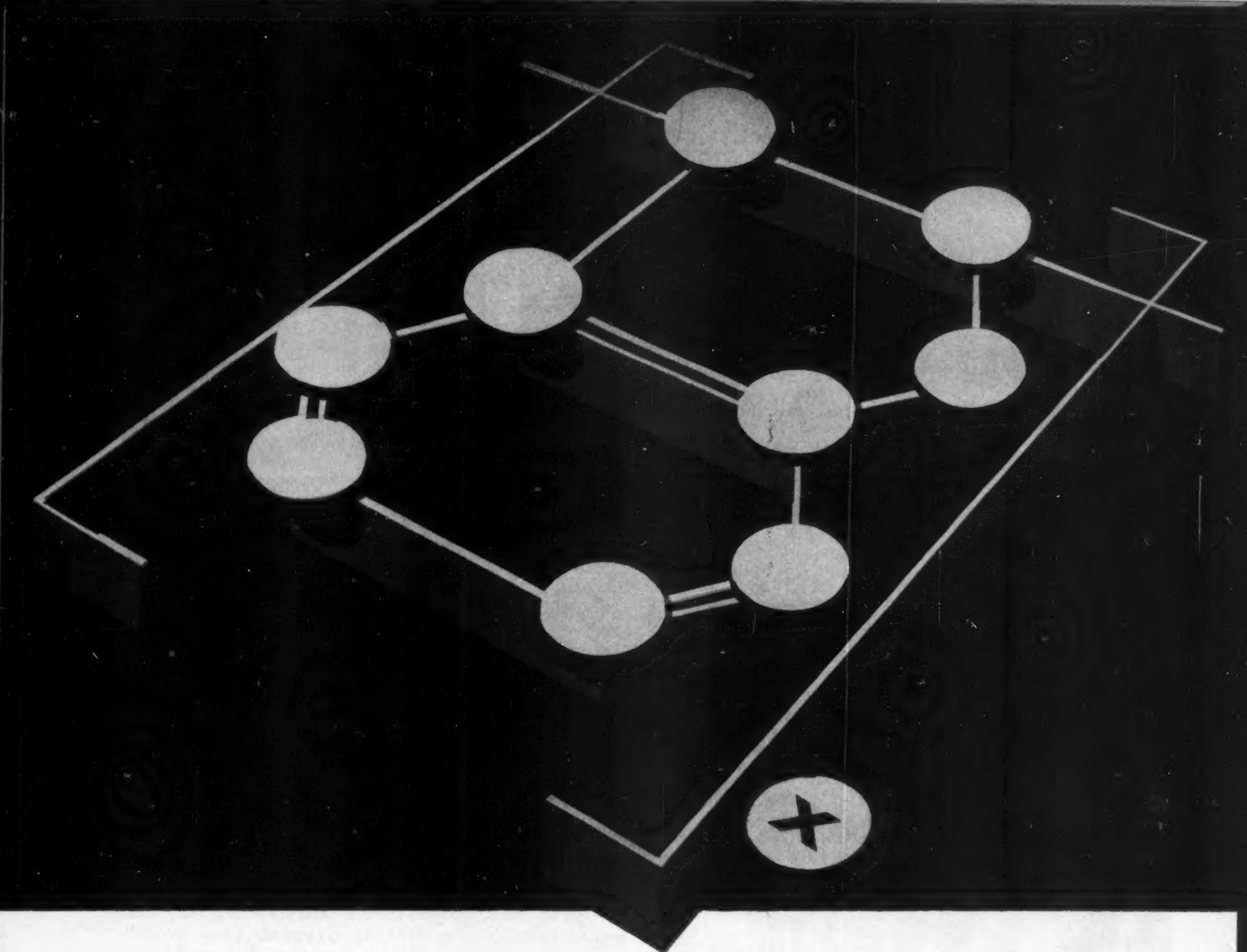
BALL MILLS



JAW CRUSHERS



APRON FEEDERS



Neville Coumarone-Indene Resins Have Improved Many Products—Yours Could Be One Of Them

In the manufacture of many products from paints to rubber tires and floor tile to chewing gum, Neville resins have long proved their ability to help make better looking, longer wearing, more salable merchandise. Neville produces an extremely wide range of coumarone-indene resins under the most exacting of specifications, and conducts broad and constant research on their mutually profitable use in many types of products. If you have an item which is conceivably applicable, we suggest you send for further information. Without obligation, our chemists will work with yours in developing the application and selecting the proper grade for the job. Use the coupon below.

Neville Chemical Company • Pittsburgh 25, Pa.

Resins—Coumarone-Indene, Heat Reactive, Phenol Modified Coumarone-Indene, Petroleum, Alkylated Phenol • **Oils**—Shingle Stain, Neutral, Plasticizing, Rubber Reclaiming • **Solvents**—2-50 W Hi-Flash, Wire Enamel Thinners.

NEVILLE

Please send further information on Neville Chemicals.

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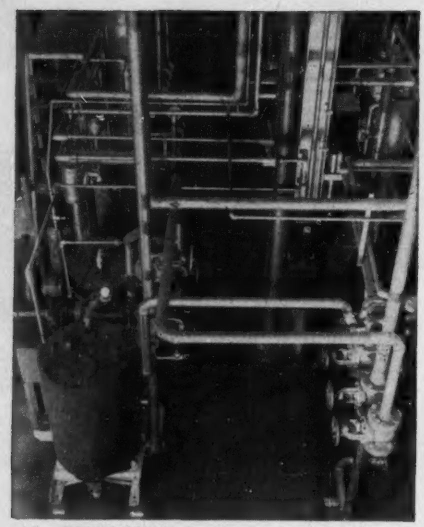
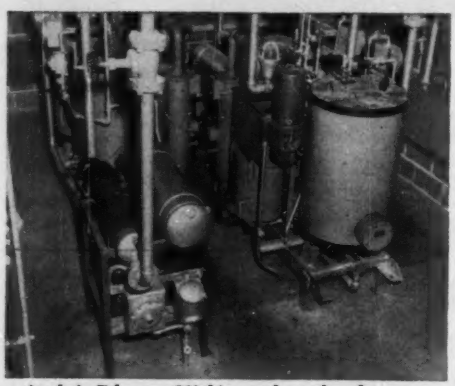


Two BWC-250 Lectrodryers work in the gas purifying room at Carboloy's Detroit plant.

Because moisture would impair quality, Carboloy DRY hydrogen to −80° F.

Lectrodryers DRY the hydrogen used in sintering and brazing operations*



At their Edmore, Michigan plant they have two BWC-250 Lectrodryers in the power plant.

MOISTURE in the hydrogen used to fire sintering furnaces would break down, freeing oxygen. This would form oxides, causing inclusions in carbides. It would consume the aluminum intended for alloying in magnets. Carboloy, Department of General Electric Company, avoids those hazards by removing every trace of moisture to dewpoints below −80°F.

Carboloy's cemented carbides, Hevimet and Alnico permanent magnets are all produced in hydrogen-fed furnaces. You see one here. As evidence of the extensiveness of these operations, the Detroit plant alone is capable of producing a million cubic feet of hydrogen a week. Lectrodryers can DRY that volume, staying on-stream continuously, without interruption.

Metallurgical operations elsewhere similarly employ gases dried by Lectrodryers. Your manufacturer of controlled atmosphere generators can advise you on their use, where DRY gases are indicated.

Pittsburgh Lectrodryer Company, 303 32nd Street, Pittsburgh 30, Pa. (a McGraw Electric Company Division).

In England: Birlec, Limited, Tyburn Road, Erdington, Birmingham.
In France: Stein et Roubaix, 24 Rue Erlanger, Paris XVI.
In Belgium: S. A. Belge Stein et Roubaix, 320 Rue du Moulin, Bressoux-Liege.

LECTRODRYERS DRY WITH ACTIVATED ALUMINAS

LECTRODRYER

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• Soap solution • Calcium hypochlorite • Water containing abrasive particles • Carbon slurry • Ferric hydroxide • Soap solution containing sand and ground glass • 25% grape juice concentrate • 50% caustic soda • Ferric sulphate • Ammonium sulphate • Demineralized water • Trisodium phosphate • Reactivated carbon • 1% chlorine solution • Sulphuric acid • 10% chromic acid • Humic acid • Weak black liquor • Waste sulphite liquor • Bleach liquor • Slurries • Acid mine water • Liquid latex • Alkylaryl sulfonate • Sodium hydroxide • Calcium hydroxide • Calcium bisulphite • Calcium hypochlorite • Demineralized water

One pump handles all these problem liquids

DE LAVAL CPO PROCESS PUMP

WITH KK-20 STAINLESS STEEL

CAPACITIES TO 2,000 GPM
HEADS TO 200 FT.

The De Laval CPO Process Pump has stainless steel parts where it comes in contact with the liquid. The casing, end head, stuffing box, impeller, seal ring and gland are all of De Laval KK-20 (20-28 stainless with molybdenum and copper). The shaft and lock nut are made of other suitable stainless steels. • Three bearing pedestals accommodate nine wet end sizes. Off-the-shelf parts in ferrous and nonferrous combinations permit changing size or metallurgy after installation. CPO pumps are available with both conventional packing and mechanical seals.

WRITE FOR BULLETIN 1125-B

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY

803 Nottingham Way, Trenton 2, New Jersey

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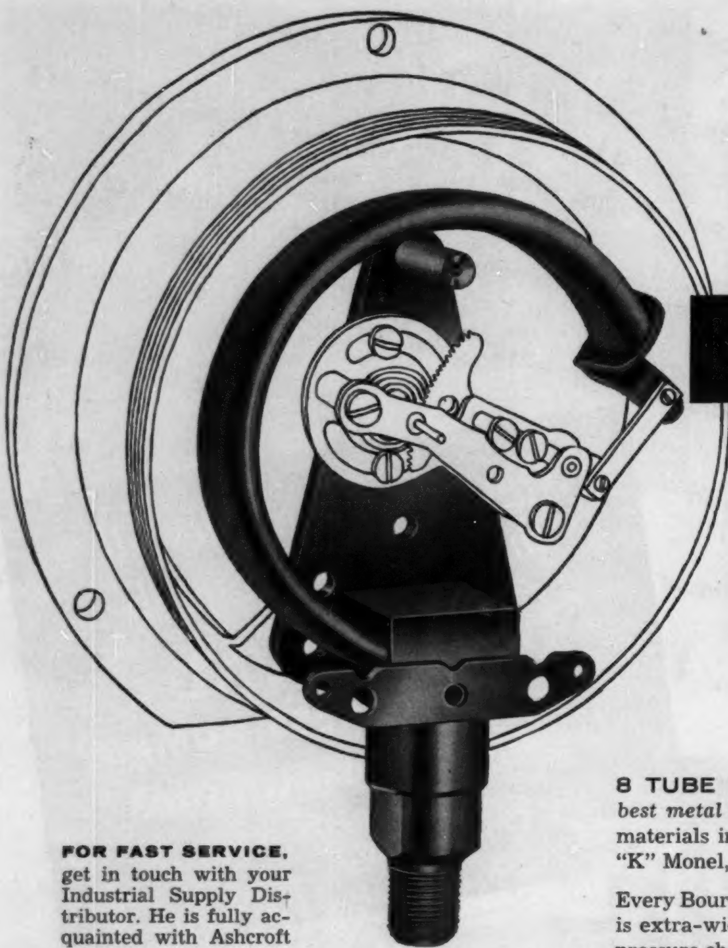


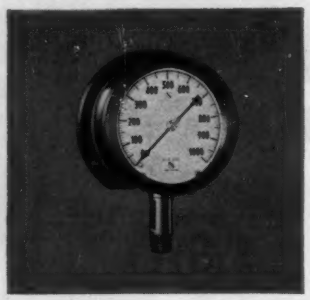
Why does the BOURDON TUBE in the ASHCROFT DURAGAUGE insure sustained accuracy?

8 TUBE MATERIALS permit selection of the *best metal* for particular service conditions. These materials include phosphor bronze, alloy steels, "K" Monel, stainless steels, and beryllium copper.

Every Bourdon tube used in the Ashcroft Duragauge is extra-wide – highly sensitive to slight pressure changes. Socket and tip joints are welded or brazed, then stress relieved after assembly, to assure maximum safety and uniform structure for highest corrosion resistance and strength. Each tube assembly is "whip tested" at pulsating pressures approximately 50% higher than its pressure rating to insure calibration stability.

The Ashcroft Duragauge is available with all-stainless-steel movement or stainless steel with nylon bearings and pinion gear. A choice of case designs and materials, dial sizes and pressure ranges readily satisfy the most exacting requirements. Whatever the working pressures or corrosive conditions of your operations, specify Ashcroft Duragauges and be sure of highest sustained accuracy and long service life.

FOR FAST SERVICE, get in touch with your Industrial Supply Distributor. He is fully acquainted with Ashcroft Duragauges and their proper selection for all kinds of applications.



In Canada: *Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario*

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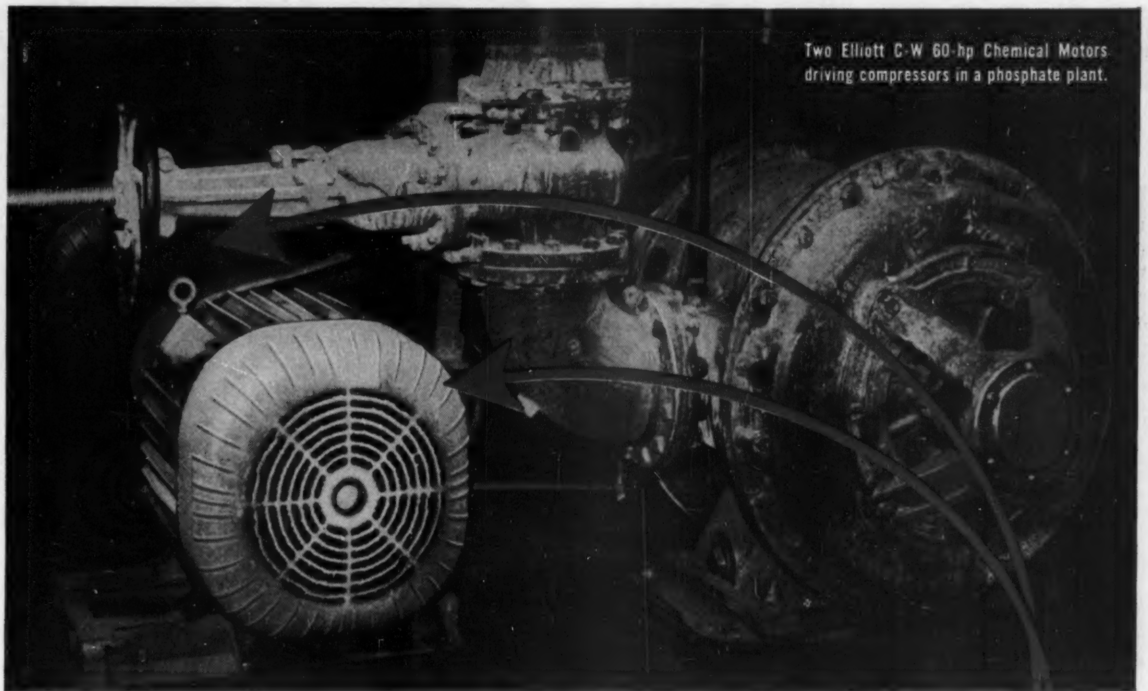
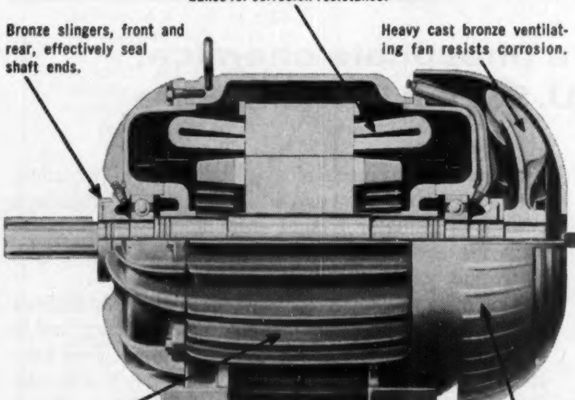
MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN-MICROSEN' INDUSTRIAL ELECTRONIC INSTRUMENTS, *Stratford, Conn.* 'HANCOCK' VALVES, *Watertown, Mass.* 'CONSOLIDATED' SAFETY RELIEF VALVES, *Tulsa, Oklahoma.* AIRCRAFT CONTROL PRODUCTS, *Danbury & Stratford, Conn. and Inglewood, Calif.* "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES, *Muskegon, Mich.*



Two Elliott C-W 60-hp Chemical Motors driving compressors in a phosphate plant.

Process service can be tough on motors!

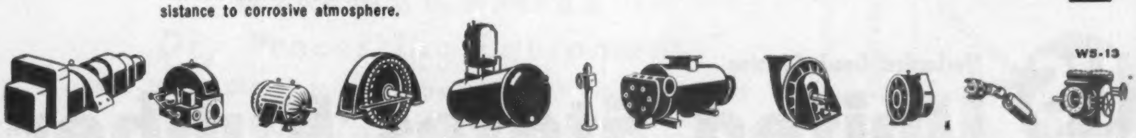
Get maximum protection with ELLIOTT chemical motors



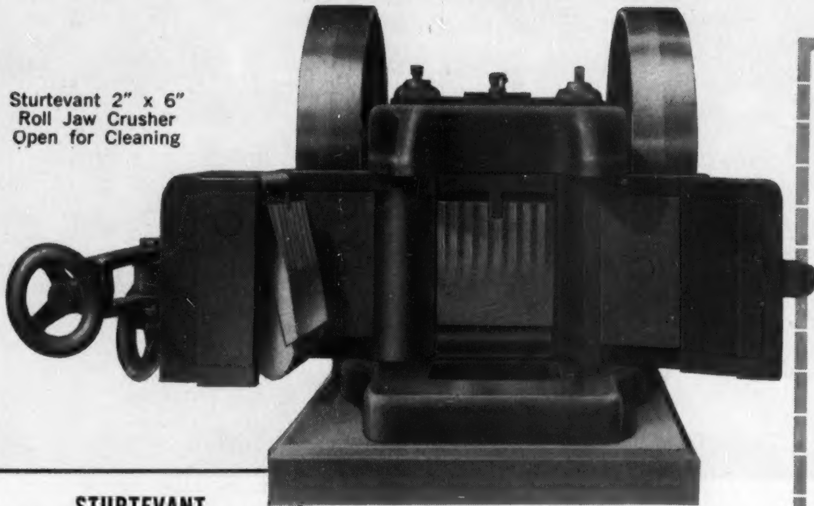
Elliott C-W Chemical Motors are especially designed to meet the grueling requirements of chemical plant duty. They offer maximum protection against corrosive fumes and vapors, dust, heat and exposure. The ribbed frames provide effective heat radiation and the fan-driven cowl-directed air blast carries off heat and prevents dust accumulation. For complete details, check with your local Elliott Field Engineer or write Elliott Company, Crocker-Wheeler Division, Jeannette, Pa.

ELLIOTT Company

WS-13



"OPEN-DOOR" DESIGN CUTS SAMPLING TIME



Sturtevant 2" x 6"
Roll Jaw Crusher
Open for Cleaning

STURTEVANT LABORATORY EQUIPMENT

ROLL JAW CRUSHER
First choice for hard rocks. Jaw opening — 2 x 6 in. Approx. capacity: 1/8 in. setting — 700 to 800 lbs. per hr.; 1/4 in. setting — 1000 to 1200 lbs. per hr.

CRUSHING ROLLS
Two sizes: 8 x 5 and 12 x 12. Outputs range from 3/4 in. to 20 mesh at capacities from 1/4 to 10 tons per hr. Performance varies with materials.

SWING-SLEDGE MILLS
For pulverizing soft, hard, tough or fibrous materials ranging from 1 in. to 20 mesh. Feed opening — 5 x 6 in. Capacities at 250 lbs. to 1 ton per hr. for 10 mesh, depending on materials.

SAMPLE GRINDER
Produces samples between 10 and 100 mesh with simple handwheel adjustments. Capacity up to 200 lbs. per hr. with 1/4 in. or finer feed.

Small-Scale Duplication of Full-Scale Production

All Sturtevant Laboratory Equipment is ruggedly constructed. So much so that it is used in regular plants for round-the-clock operations. Exclusive "Open-Door" design makes cleaning and maintenance between sample runs quick and easy.

Preferred by laboratories that are proud of their work. Users of Sturtevant Laboratory Equipment represent the "blue chips" in industry and education. Names on request. Check the coupon for full information.

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Also bulletins on machines for:

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My dry-process materials are: ____________
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The "OPEN DOOR" to lower operating costs over more years

CRUSHERS • GRINDERS • MICRON-GRINDERS • SEPARATORS
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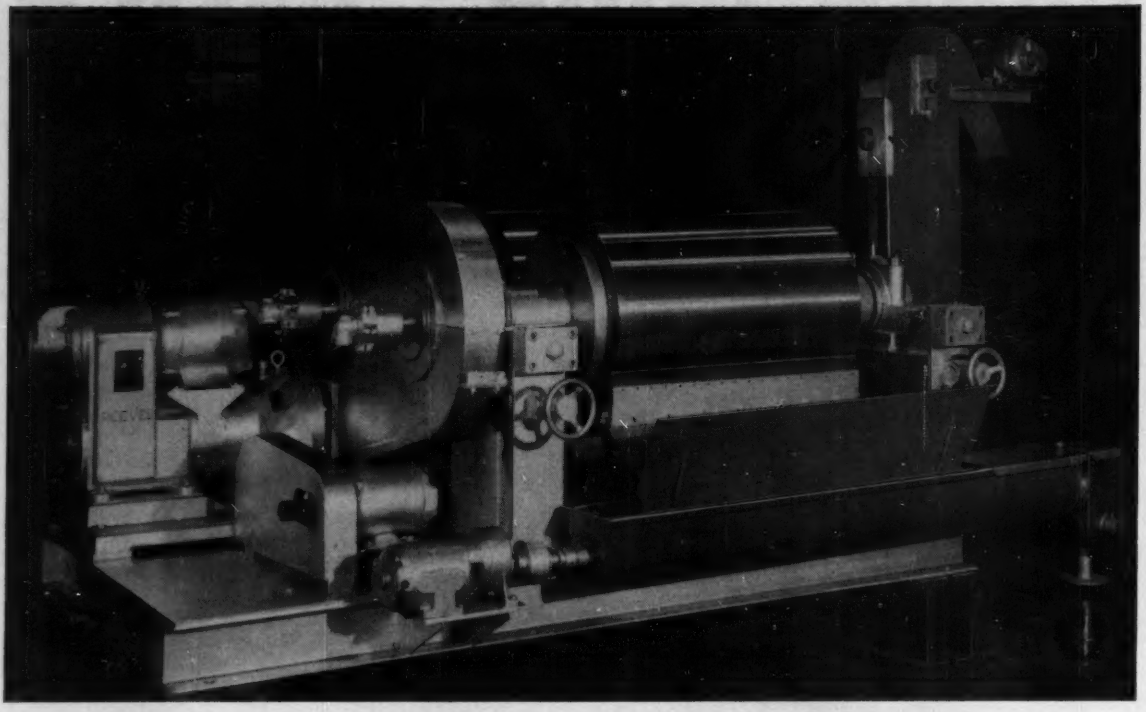
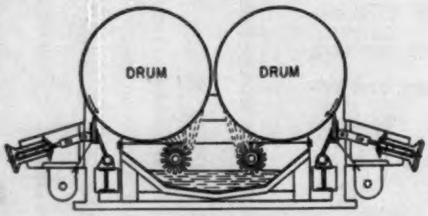




DRUM
DRUM

Getting more service hours per dollar

HOW TO SPECIFY FLEXIBLE METAL HOSE

3 simple steps can help you select metal hose for best results and longer service life

The important job of selecting the *most economical,* the *one right* flexible metal hose for your product or transfer problem can be greatly simplified by following these 3 steps:

1 Send exact specifications

Complete and exact statement of operating conditions will go far in saving you money on flexible metal hose.

First, it assures you that the connector you get will live up to your expectations. And, second, that manufacturers won't bid on hose that's "over-engineered." You'll save in the long run because you'll get the right assembly for every job.

Here is the information we need before we can give you our best suggestions:

A PHYSICAL REQUIREMENTS:

1) *Over-all length (including fittings)*
2) *Diameter (I.D. and O.D.)*
3) *Fittings—size, type, style of thread*
4) *Tolerances permitted*
5) *Quantity required*

B OPERATING REQUIREMENTS:

1) *Material to be conveyed*
2) *Operating pressures—is there shock?*
3) *Operating temperatures*
4) *Movement—lateral and longitudinal*
5) *Vibration conditions?*
6) *Expansion and contraction requirements?*
7) *Corrosive atmosphere?*

Send sketch of proposed installation if available.

2 Use standard metal hose where possible

Many standard connectors have been developed to meet problems common to many finished products—i.e., vibration. Often a standard metal hose will answer your needs as well as a special item could. We can often save you money if we know operating requirements.

3 Call the Man from Anaconda to help you select, specify, test

When selecting or specifying flexible metal hose, you'll find American's staff of trained engineers of invaluable assistance. Their advice and suggestions may help you solve or avoid many costly problems.

NEW INFORMATION

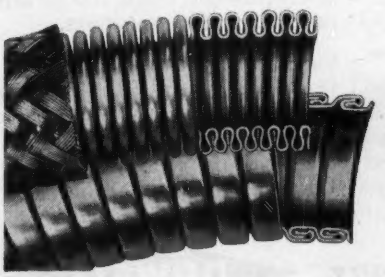
American Flexible Metal Hose and Tubing Catalog puts all the information you are looking for—both technical and general at your fingertips. Get your copy today, free of charge. Mail coupon below.

WHEREVER CONNECTORS MUST MOVE

AMERICAN

FLEXIBLE METAL HOSE AND TUBING

an **ANACONDA**® product



BASIC TYPES

CORRUGATED and STRIP-WOUND. In a wide range of sizes and styles in any workable metal. Various fittings.

THE AMERICAN BRASS COMPANY
American Metal Hose Division, Waterbury 20, Conn.

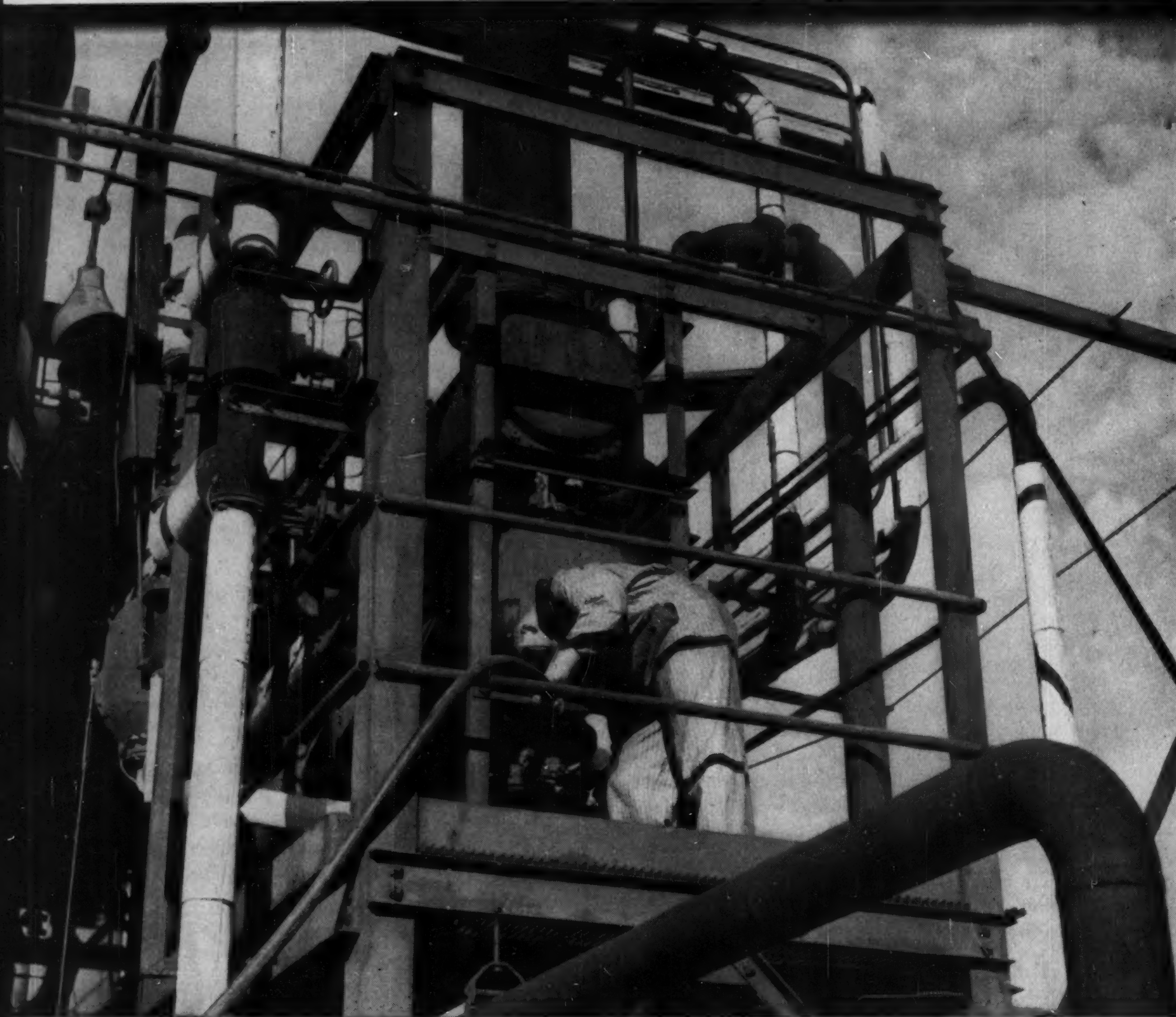
Please send me your free Quick Reference Catalog CC-400 containing basic information on all types of metal hose and tubing, fittings, etc.

NAME & TITLE..

ADDRESS..

COMPANY..

CITY, ZONE, STATE..



For years, makers of cough syrups, lozenges, lotions and other drug and cosmetic preparations have used Glycerine to provide demulcent, humectant or solvent action. Recent research with new thickening agents indicates that these properties of Glycerine will soon be extended to a whole new range of pharmaceutical preparations.

Glycerine has been known for years to be compatible with conventional water soluble gums and gelling agents such as Gum Arabic and Karaya. New studies show that Glycerine is also compatible with a majority of the new synthetic gums. In most cases, Glycerine supplements the bodying action of these gums, and the resultant formulations are relatively unaffected by freezing and thawing.

Other fields, too, will benefit from this compatibility of Glycerine. Nontoxic lubricants are now possible. Important improvements in printing inks, grinding and polishing pastes, gasket seals—all making use of Glycerine's unique balance of properties—are promised.

The versatility that has won such wide acceptance for Glycerine in the past continues to open new doors to chemical progress. In paints, foods, pharmaceuticals, packaging . . . for tomorrow's surge of specialties . . . in new formulations, reactions and processes, nothing takes the place of Glycerine.

This balanced group of properties keeps Glycerine's usefulness growing

HYGROSCOPICITY · STABILITY ·
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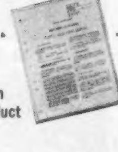

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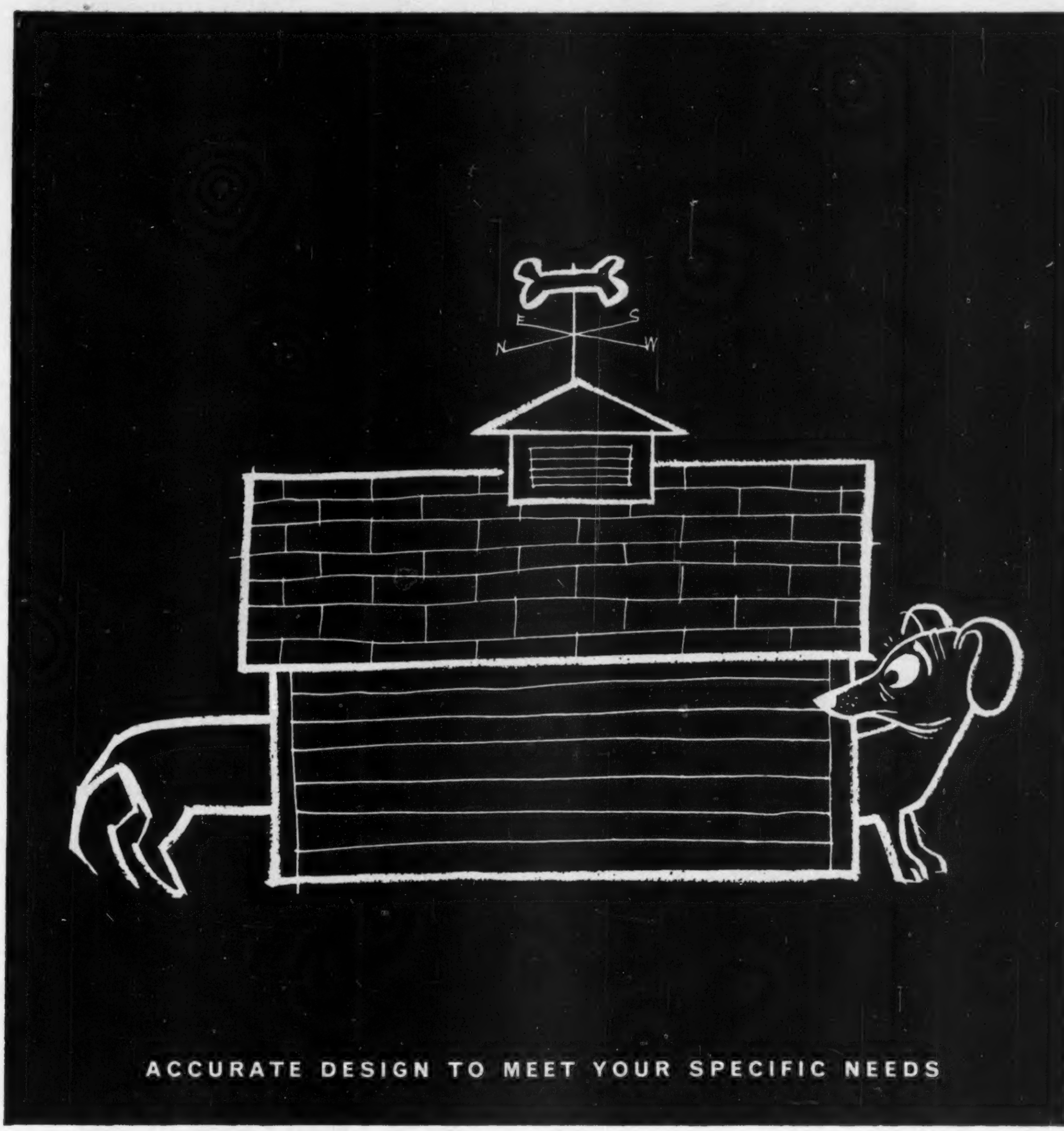

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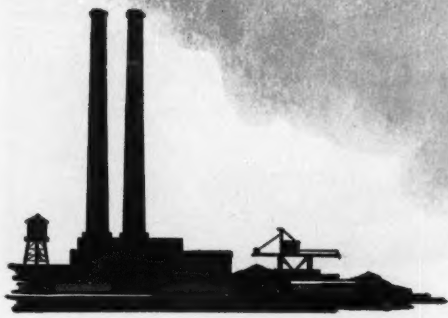

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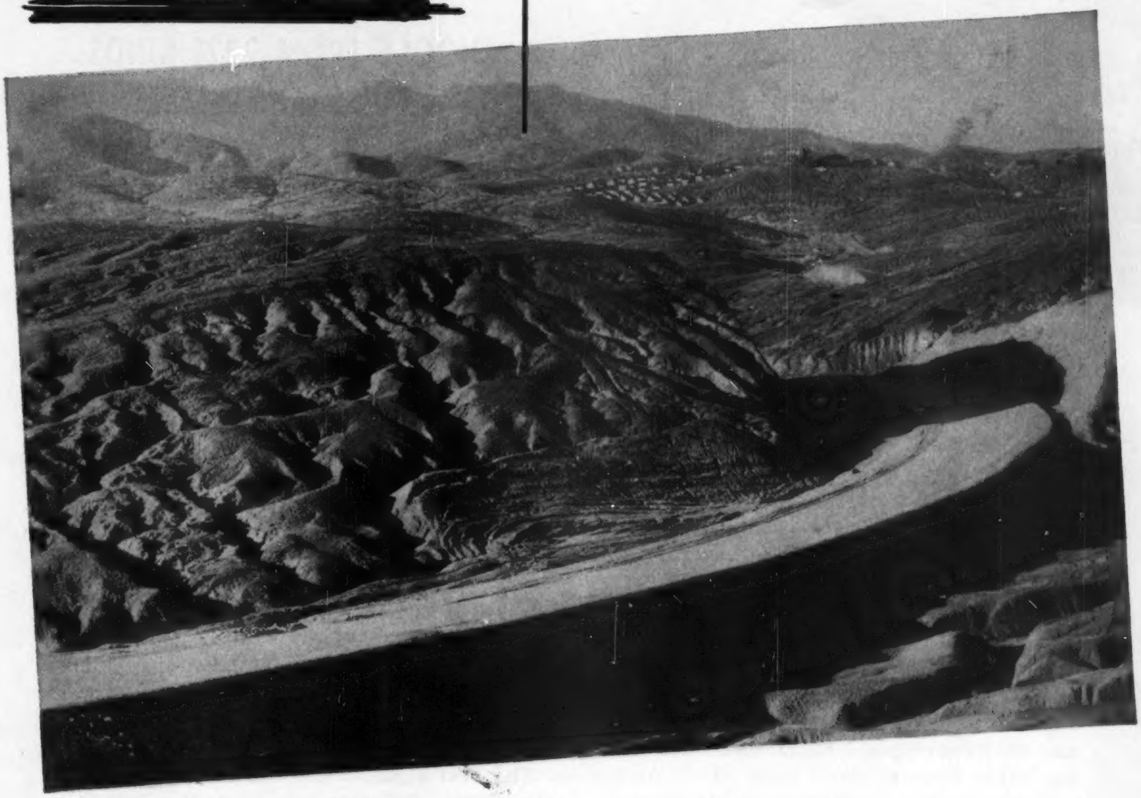

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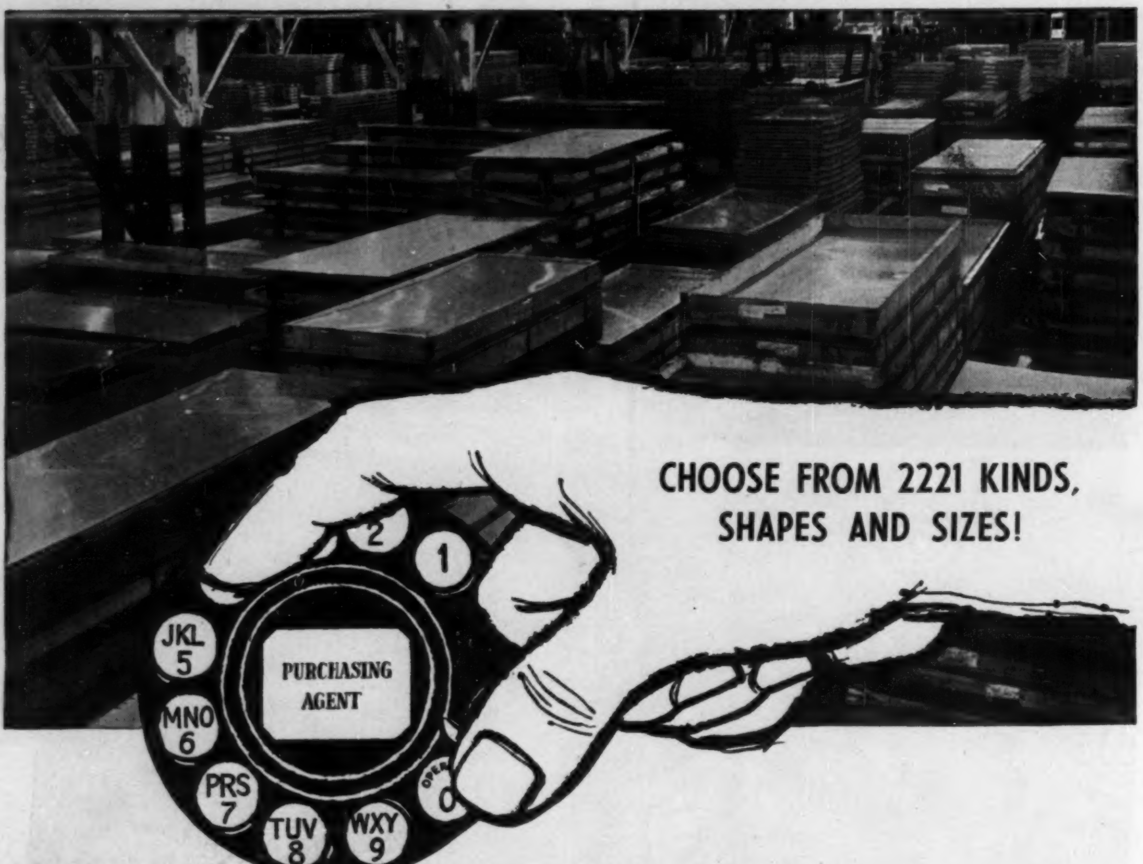

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Chemical Engineering
June 1956

Handling Compressible Fluids

SCARCELY a plant in the chemical process industries lacks at least an air compressor for supply of plant air. In many plants compressors serve as process equipment to help bring about reactions and phase separations, or to provide refrigeration. Many plants use them in materials handling, in liquefying or storing gases, in agitation, in lifting liquids from wells or moving them in pipes, and in providing instrument air. Most plant shops use them to power air tools and, in processes with explosion hazards, they often drive air motors on agitators and other mechanical equipment.

Compressors, to use the term in its broadest sense, move compressible fluids from suction pressures as low as 10^{-7} mm. Hg up to atmosphere, in which case they are vacuum producers. They may move fluids with little pressure increase in the atmospheric range, then being called fans and blowers. Finally, the true compressor takes suction at about atmospheric and delivers the fluid at pressures ranging upward to 40,000 psig. in commercial processes, or still higher experimentally. In some processes, particularly the high-pressure industries such as ammonia and polyethylene, compressors account for a sizable part of the plant's capital cost.

Many principles come into play in compression, among them use of a second motive fluid, as in diffusion pumps and ejectors; physical entrapment and positive compression, as in positive reciprocators and rotaries; and radial or longitudinal acceleration by moving surfaces, as in the dynamic types included among fans and most blowers, as well as centrifugal and axial-flow compressors. This 64-page special Report, taking up compressor application and selection, compressor types, and finally drivers, control and accessories, has the purpose of helping the engineer in understanding and selecting the best compressor for any given purpose.

The editors extend appreciation to our ten authors, and particularly to the Compressed Air and Gas Institute for the initial inspiration and much assistance during the formative stages of this project.

C. S. CRONAN
T. R. OLIVE

How This Report Got Started . . .

Schramm and Engelhart (left to right) consider some aids prepared by the Institute for colleges and industry.

This Report got started about a year ago as the result of a 30-minute telephone call from Catasauqua, Pa. That day Kemp Engelhart, vice-president of the Fuller Co., called to remind us we hadn't done a good job on compressors and their use in the chemical process industries in a long time—and a complete job—never.

We were interested, especially when he offered the full cooperation of the Engineering Education Committee of the Compressed Air and Gas Institute. Yes, he was chairman. Les Schramm, Institute president, would help in any way possible. One thing led to another—conferences in New York, long distance calls to Ted Powers, educational director, in Cleveland, appearance of two editors before the Engineering Education Committee at Hershey, Pa. With their help we outlined the problem, decided what articles would be needed.

Compressed Air and Gas Institute is a forward-looking organization of compressor and air tool makers which for more than 15 years has devoted a large part of its effort toward the education of engineering students of 166 engineering schools in numerous aspects of compressed air and gas production, handling and use. Similar efforts have extended to industry and the engineering public. The Institute has produced film slides, a color-sound motion picture, many pamphlets on various aspects of the problem. It assists in article development and maintains a speakers' bureau. Its most ambitious effort was the preparation and publication of the first edition of "Compressed Air Handbook," which in its second edition was published by McGraw-Hill.

Institute president in 1954 and 1955 was Leslie B. Schramm, secretary and sales manager of Schramm, Inc., at West Chester, Pa. Schramm, a BS graduate of Haverford, joined his company in 1938. He was the first chairman of the Institute's Engineering Education Committee and now heads the committee on stationary single-acting compressors.

For the past three years through 1955, George Kemp Engelhart headed the Engineering Education Committee. Englehart holds degrees from Iowa State and George Washington University, the latter an LLB. He is vice-president and patent attorney of the Fuller Co., Catasauqua, Pa., has retired as a colonel from USAR, and holds the Legion of Merit. During World War II he was director of the Internal Security Division of OPMG. He has authored books and many papers, especially on cement technology.

. . . And the Authors Who Helped Us Complete It

Compressor Application 178

PAUL R. DES JARDINS

Des Jardins' 1938 degree at MIT was in business and engineering administration. There he also studied chemical engineering. Before, between and since two periods of Navy service he has been with Worthington, Harrison, N. J., and manages the petroleum and chemical division.

Compressor Selection 188

WILLIAM T. ALDERSON

Alderson's professional life has been spent largely with compressors, although his training at Johns Hopkins was in electrical engineering. He went with GE in 1923 after receiving his BS, then joined Ingersoll Rand in New York in 1927. Now manager of compressor engineering.

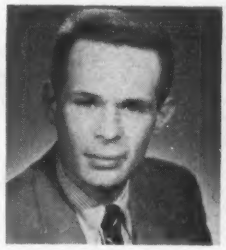
Steam Jet Ejectors 196

ROBERT FRUMERMAN

Frumerman's MS in ChE is from Carnegie Tech. He first worked on process plant design for Blaw-Knox, and later on all aspects of steam ejector engineering for the Elliott Co., Jeannette, Pa. He now is manager of process application and design in Elliott's development department.

Axial Compressors 212

ROBERT E. CLAUDE



Claude is an application engineer in Allis-Chalmers' compressor department at Milwaukee, Wis. Holding a University of Wisconsin BS in aero engineering, he is working on his MS. During his three years in the USAF he received the Distinguished Flying Cross and Air Medal.

Fans and Blowers 202

ARTHUR N. ROGERS

Rogers is division sales engineer in the sales development section of Westinghouse's Sturtevant Division, Boston. He graduated as a mechanical engineer in 1948 from Northeastern University and has since been with Sturtevant in work on precipitators, heat transfer products, and fans.

Reciprocating Compressors 216

EVERETT L. CASE

Case holds a liberal arts AB from Canisius and a BS in ME from the University of Buffalo. His service of nearly 20 years with Worthington Corp. has involved testing and research, applications, and sales. Now situated at Buffalo, he is assistant manager of compressor sales.

Rotary Compressors and Vacuum Pumps 224

WILLIAM L. BRUCE

Bruce is a mechanical engineering graduate of University of Tennessee, and is a professional engineer in the State of Wisconsin. Much of his time since joining Allis-Chalmers Mfg. Co., in Milwaukee, has been in engineering operations with compressors and blowers.

WILLIAM A. SCHUBERT

Schubert received his academic training at Marquette University. Like his coauthor, he has devoted much of his time with Allis-Chalmers to work on compressors and blowers. The two authors, together, total more than 30 years of association with Allis-Chalmers.

Centrifugal Compressors 206

EDWARD S. LEONARD

Leonard graduated in mechanical engineering, Penn State, 1948. Since then, except for three Army years as a heavy equipment maintenance engineer, he has been with Clark Bros. Co., Olean, N. Y. He is at present manager of Clark's centrifugal compressor engineering sales.

Drivers, Controls, Accessories 227

RICHARD N. HANCOCK

Hancock's degrees, BS in ME and EE from VPI, in 1941 led to work for Ingersoll Rand on compressor engineering. Since 1945 he has been in Foster Wheeler Corp.'s process plant design division, New York, and is now in charge of selecting pumps, compressors, prime movers.

Handling Compressible Fluids

IN CHEMICAL PROCESSING

Paul R. Des Jardins

Compression of gases and air, and evacuation of enclosed spaces, are essential in numerous process industries. Given here is a broad survey of many of these applications.

Since 1920 the growth of the bulk organic chemicals industry has been paralled by improvements in the design of equipment for handling compressible fluids. Prior to the rise of the organic chemicals industry, compression equipment in use throughout the chemical process field was primarily for handling air, natural gas, ammonia, and kiln gases. Today's designs of equipment have evolved with the growth of the production of ammonia, the production of ethylene, the spread of pipeline systems for transporting natural gas, and the use of Freon as a refrigerant. The most recent design developments are the result of the larger scale chemical process plants being constructed, and the need for oil-free air and gas to prevent contamination of catalysts and to enhance instrument operation.

The handling of compressible fluids in the chemical industry through the use of compressors, ejectors, fans, blowers, and vacuum pumps is an integral part of the unit operation of fluid flow. A compressible fluid can be evacuated from a system or injected into a system to help produce the desired pressure-volume-temperature relationship necessary to allow a reaction, or a unit operation such as absorption, adsorption, condensation, distillation, or evaporation, to proceed at an optimum rate, or produce a desired change of phase. In filtration, materials handling and mixing, a compressible fluid can be evacuated from a system or injected into a system to allow collection of a solid on a filter surface, to fluidize small solids and enable the solids to be handled as a fluid, and to agitate solids or liquids. Compression is often used to assist the storage of gases in containers, by liquefaction or, at least, by forcing into less volume.

The largest numbers of machines for handling compressible fluids in the chemical industry are those compressors, blowers, and ejectors used for handling air. Air for instrument operation, the actuation of controls, and for general utility use is required in almost every chemical process plant. A 100 psig. air system is commonly used for utility service, to operate portable tools such as those for cleaning tubes, and to operate hoists, packaging machinery and other mechanical equipment. Compressors for supplying air at approximately 250 psig. pressure are used as a source of compressible fluid for starting large gas and diesel engines.

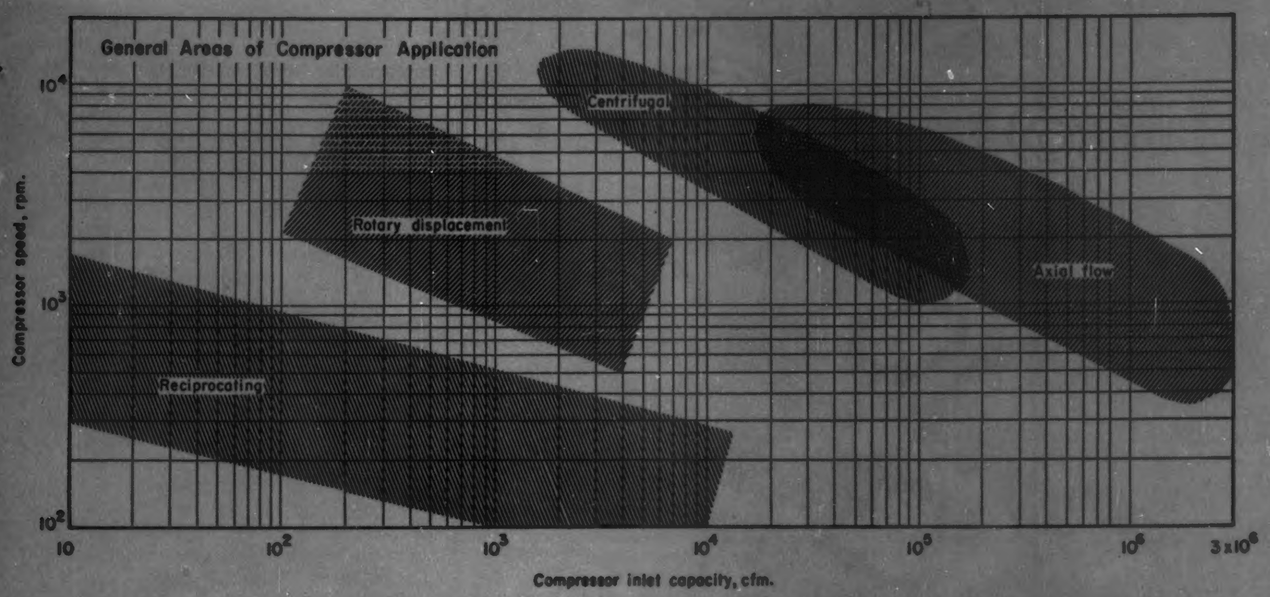
Air for oxidation is the most widely used chemical application. The required air pressure may be furnished by any type of compressing equipment, ranging from fans discharging at a few inches of water pressure, to multi-stage reciprocating compressors at 3,000 psi. Large-scale continuous process commercial plants use oxidizing air for making such products or intermediates as synthesis gas, ethylene oxide, formaldehyde, methanol, acetaldehyde, phthalic anhydride, and nitric acid.

Every type of blower and compressor is used to supply air for the regeneration of catalysts, particularly in those processes where the catalyst fouls up with a carbon deposit and the deposit can be removed by burning. Universal application is also found for every type of blower and compressor to supply inert gas for purging process systems and for blanketing some operations.

Air Separation Plants

In those processes where oxygen is used instead of air, the oxygen required is made from air with the aid of compressing equipment. Many liquid oxygen plants use reciprocating air compressors discharging at pressures up to 3,000 psi. There have been large-scale air fractionation plants built in recent years utilizing centrifugal compressors. However, most centrifugal compressors have been applied to those plants requiring air pressure around 100 psig. Most of the air separation plants being offered today to supply tonnage oxygen or nitrogen for process use require air in the 100-600 psi. range, depending upon the use to which the product is applied.

Expanders—which are air engines or turbines—are used in oxygen plants to produce refriger-



ation. In general, small plants use reciprocating expansion engines and large plants use turbine-expanders. In these expanders air does work, loses heat, and is discharged at a lower temperature and pressure. Operating temperature is in the neighborhood of —300 F. Although the prime purpose of the expander is to produce a refrigerating effect, the machines can be used to drive a generator or a compressor.

Non-Lubricated Compressors

In the design of expanders and oxygen compressors every effort is made to assure that lubricating oil does not come in contact with the air or oxygen being handled. The cylinders and moving parts within the cylinders of reciprocating machines are made of materials which can operate without hydrocarbon oil lubrication, and centrifugal type equipment is designed so that the oil used to lubricate the bearings cannot come in contact with any air which goes through the unit.

Within the past five years the use of non-lubricated reciprocating compressors has increased primarily due to their application in catalytic reforming processes used by oil refineries to produce highly aromatic products which can be blended to give high-octane gasoline. These same catalytic reforming processes can be used to produce benzene, toluene, and xylene. If the demand for these chemicals should become greater than the demand for high-octane for motor fuel, a number of the present catalytic reforming units could be revamped to produce benzene, toluene, and xylene by addition of separation facilities.

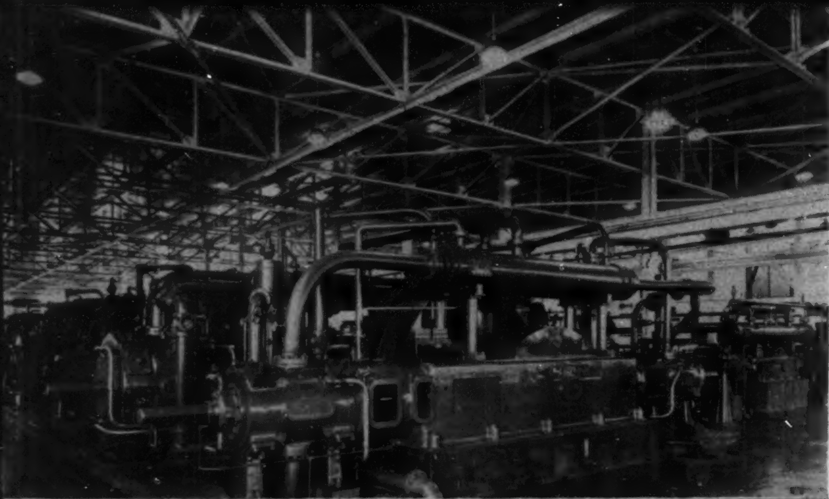
Non-lubricated compressors are used in some of the catalytic reforming processes to handle recycle gas, which is mainly hydrogen, at discharge pressures of between 200 and 800 psi. The hydrogen evolved during the catalytic reforming process can be used as a raw material for the manufacture of ammonia or for various desulfurization processes used to upgrade refinery products.

Some of the desulfurization processes operate at pressures closely related to those of catalytic reforming and require similar non-lubricated compressors. The non-lubricated units are used in some of these processes to eliminate the difficulty which would be encountered if the lubricating oil used in the cylinders of standard

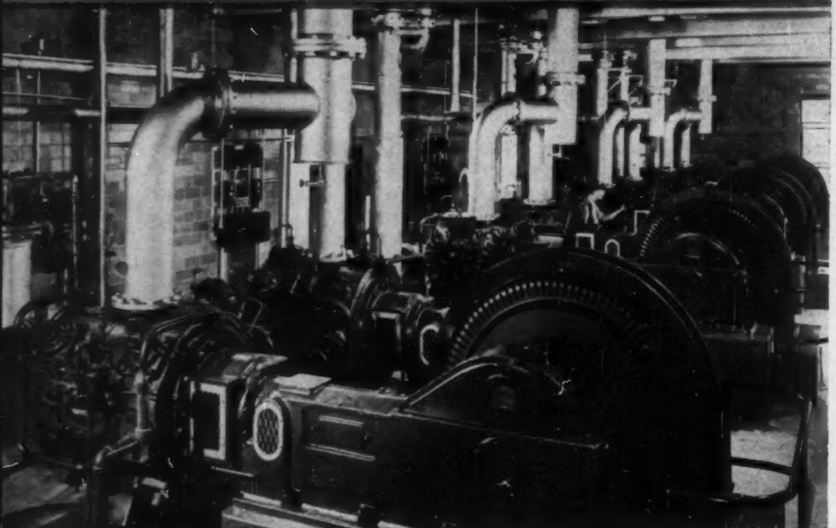
General Limits of Compressors and Vacuum Pumps

Compressor Type	Approx. Max. Commercially Used Disch. Press., Psia.	Approx. Max. Compression Ratio per Stage	Approx. Max. Compression Ratio per Case
Reciprocating	35,000	10	—
Centrifugal	4,200	4	10
Rotary displacement	125	4	4
Axial flow	90	1.2	6

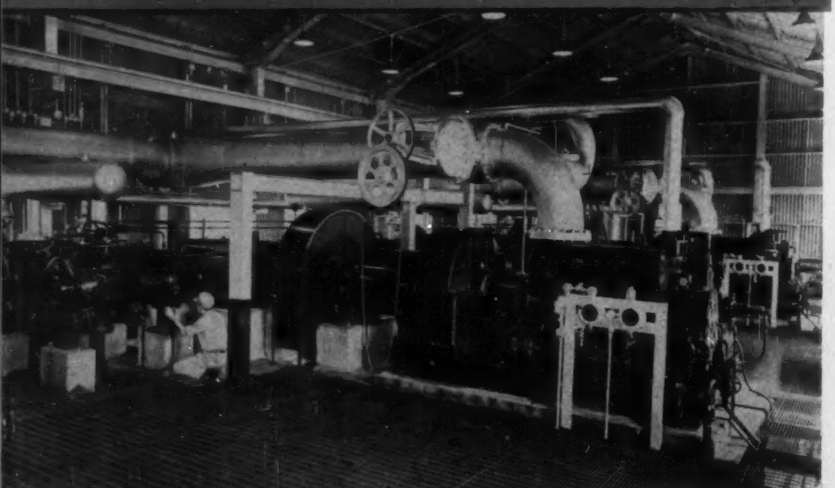
Vacuum Pump Type	Approx. Suction Press. Attainable, Mm. Hg Abs.
Centrifugal	6
Reciprocating	3×10^{-1}
Steam jet ejector	5×10^{-2}
Rotary displacement	1×10^{-5}
Oil diffusion	1×10^{-7}



Four-stage 2,000-hp. compressors in an air fractionation plant.



Four non-lubricated duplex air compressors in a chemical plant.



Balanced opposed turbine-driven recycle compressor in a reforming plant.

compressors were carried through the system and fouled the catalyst.

However, other catalytic reforming processes allow the use of regular oil-lubricated compressors.

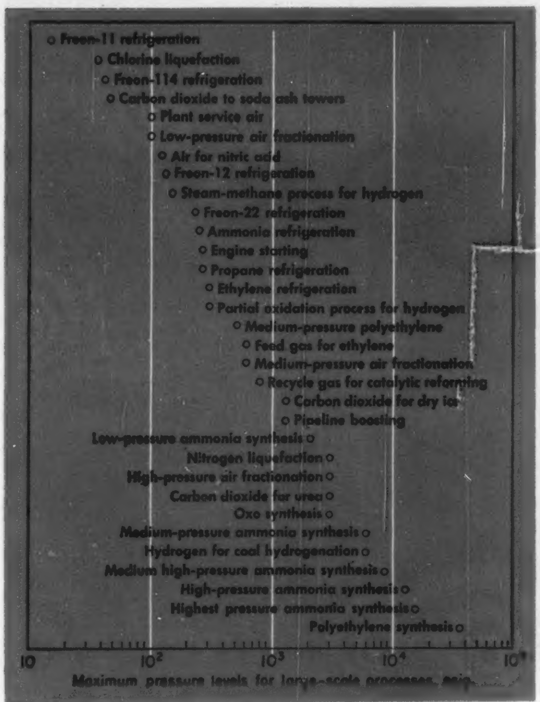
Early applications of non-lubricated compressors in chemical process plants were limited in number because of the high cost of maintenance. In recent years the decrease in maintenance costs—which results largely from improvement in the homogeneity and texture of the carbon rings used for the piston and for piston rod packing—has enabled non-lubricated reciprocating compressors to be more widely applied for supplying oil-free air to processes and instruments.

In deciding on the use of non-lubricated compressors it is necessary to weigh the higher maintenance costs and higher initial cost compared with a standard oil-lubricated compressor. It is necessary to compare also the cost of separating oil carry-over to the process from a standard compressor. In many cases the necessary oil separation can be accomplished at a cost less than the difference in initial and maintenance costs between non-lubricated and lubricated compressors.

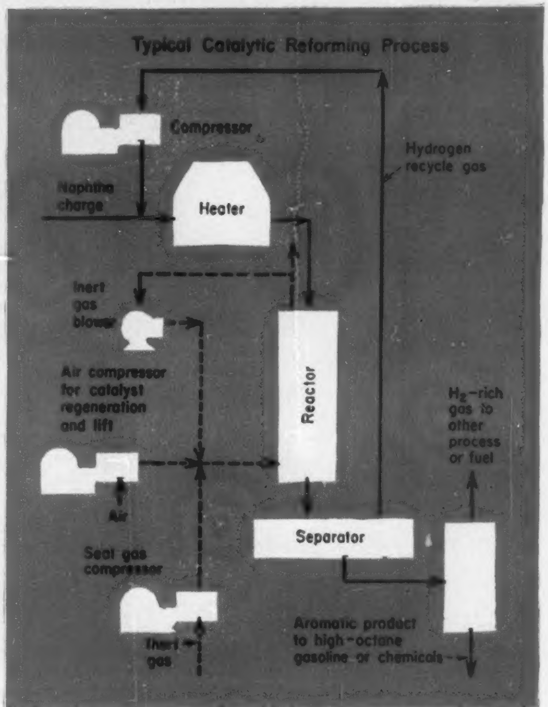
Among the processes requiring equipment capable of handling compressible fluids at pressures over 2,000 psi. are ammonia, methanol, urea, Oxo chemicals, hydrogenation, the manufacture of polyethylene and the production of high purity liquid oxygen. In these processes pressure is required in order to achieve a reaction or separation at the optimum pressure, volume, and temperature conditions for a commercially feasible equilibrium rate. In some cases the pressure condition produced allows a change of phase to be accomplished for refrigeration, gas separation, or product removal.

Ammonia Synthesis

The manufacture of ammonia in recent years has required more investment in compressible fluid handling equipment than any other single major chemical process. The cost of the compression installation for an ammonia plant can run as high as 20% of the total plant cost. The production of synthetic methanol can be accomplished with compression equipment very similar to that required for ammonia



Maximum pressures in typical large-scale processes.



Reforming process makes high-octane gas or chemicals.

manufacture. The primary compressors used in an ammonia plant may handle the hydrogen-nitrogen synthesis gas at pressures up to 15,000 psi.

Commercial ammonia processes can be grouped into three classes as far as compression equipment is concerned. One class, which comprises the largest number of ammonia plants built, covers the 2,000 to 6,000 psi. range. The other two classes fall in the 8,000 to 12,000 and 12,000 to 15,000 psi. ranges.

Since all of the synthesis gas is not converted to ammonia during the first pass through the reactors, either recirculator compressors or ejectors are used to recycle the unreacted synthesis gas. The recirculator takes suction at a pressure about 10% lower than the discharge pressure of the primary compressors. Because the high-pressure cylinder of the primary compressor takes suction at about 40% of the discharge pressure, and the recirculator takes suction at about 90% of this same discharge pressure, the recirculator cylinders are considered to present a more difficult compression problem from a design standpoint than the primary compressor high-pressure cylinders.

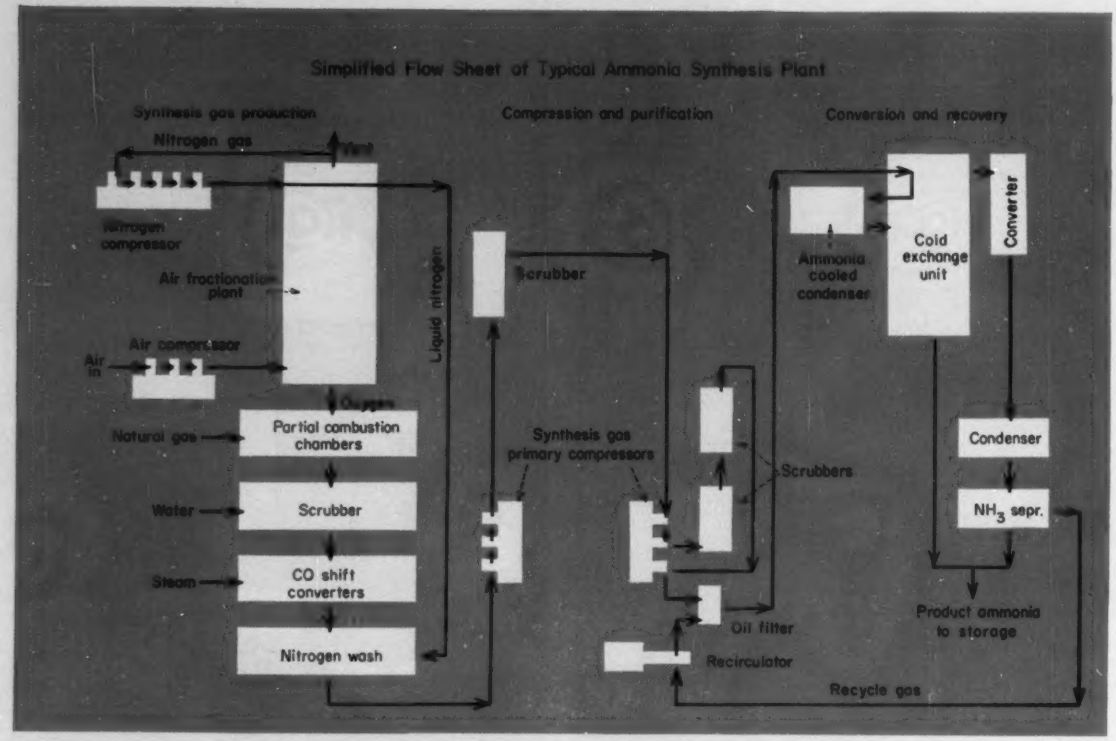
Primary compressors and recirculators can be motor-driven, gas-engine-driven, or steam-driven. Although most ammonia plants have recirculators separate from the primary compressors, there are applications where the circulator cylinder is on the same frame as the primary cylinders. The advantage of having circulator cylinders on the same frame is mainly that of first cost. Recirculators as separate machines allow a wider latitude of control of the amount of recycle and make feasible the purchase of a slower speed machine.

On comparable machines, even those operating at equal piston speeds, a unit running at fewer revolutions per minute will have fewer reversals per minute at the packing, fewer valve openings and closings per minute, and can be expected to require less maintenance. The decision as to whether or not to use motor-driven, engine-driven, or steam-driven equipment with integral or separate recirculators is determined primarily by the cost of electricity, gas, oil, and steam at the plant site, and by the manner in which plant payout is calculated.

Ammonia Synthesis Gas

The manufacture of ammonia synthesis gas requires a source of hydrogen and a source of nitrogen. Hydrogen production by steam-methane reforming can be done commercially at pressures in the 150-psi. range. Hydrogen produced by partial oxidation processes can be done economically at pressures in the 300-psi. range. Older steam-methane reforming plants operate the reforming section at practically atmospheric pressure, whereas most of the newer plants operate at elevated pressures. The production of hydrogen at these elevated pressures cuts down on the amount of power required to compress the synthesis gas for making ammonia.

In a number of ammonia plants using the partial oxidation process for producing hydrogen, nitrogen from the air fractionation plant is compressed to approximately 3,000 psi. in order that it



Many modern ammonia plants use air fractionation and natural gas as sources of synthesis gas.

may be liquefied readily. The liquid nitrogen is used as a wash to remove impurities from the hydrogen stream and enough nitrogen is vaporized to give the required nitrogen-hydrogen mixture for making ammonia. The large compressors in many of the newer ammonia plants handle air, nitrogen, synthesis gas, and recycle gas. In some instances cylinders for several of these services are on the same compressor frame.

At pressures above 8,000 psi., the ammonia can be separated from unconverted synthesis gas by water cooling. At pressures lower than 8,000 psi., or if an adequate supply of cooling water is not available, it is necessary to use refrigeration for condensing the product ammonia. An ammonia refrigeration system can be used to provide the required temperature level. The ammonia compressors used in the refrigeration system are in most cases standard refrigeration units operating at pressures up to 240 psi.

In those cases where hydrogen is obtained as a byproduct from catalytic reforming processes, electrolytic processes or coke-oven gas, there is need for compression equipment to aid in the purification of the hydrogen stream. Different temperature levels are required and a cascade refrigeration system can be used. The cascade refrigeration system combined with the liquid nitrogen wash results in the final purification taking place at around -300 F.

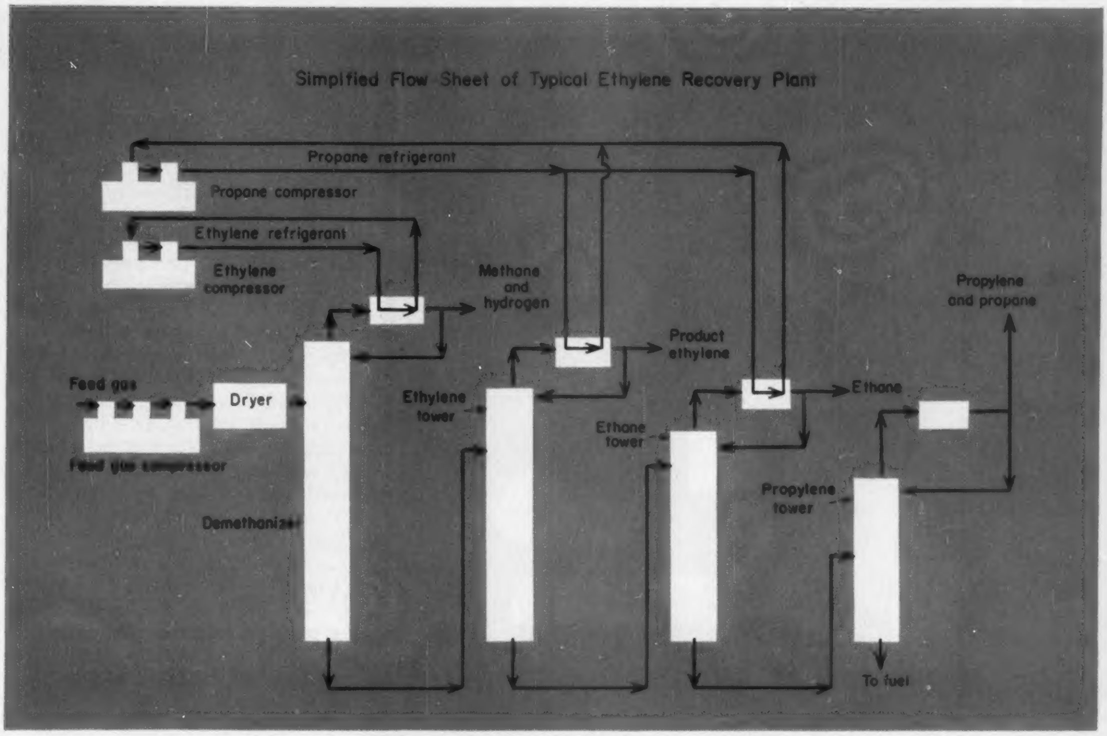
Depending upon the amount and kind of impurities to be removed from the hydrogen stream, various temperature levels are employed for their condensation and removal. The refrigeration supplied in existing plants consists of systems using ammonia or propane, ethylene, and methane. The ammonia or propane systems require compressors suitable for discharge pressures up to 250 psi. and the majority of installations are confined to temperature levels warmer than −40 F. When a colder level is required in process work, ethylene may be used down to a level of −150 F. with compressing equipment discharging at pressures up to 300 psi.

The cascade results from the use of ammonia or propane as the cooling medium to condense the ethylene in a heat exchanger. This can be carried further if a lower temperature level is desired and ethylene can be used as the cooling medium to condense methane in a heat exchanger. The methane refrigeration system can get down to temperatures around −250 F. In some hydrogen gas purification units, refrigeration at the propane and ethylene levels is used to condense hydrocarbons, and refrigeration at the methane level is used to liquefy nitrogen.

Ethylene Recovery

Along with ammonia plant compressors, the compression equipment required for the manufacture of ethylene ranks among the first from the standpoint of cost of compression equipment required for a commercial sized plant. Although there are a number of different methods for producing and separating ethylene, the majority of the plants use a low-temperature, high-pressure fractionation process for recovery of the ethylene. Ethylene is present in some refinery gases and it can be produced by cracking ethane, propane, naphthas, or gas oil.

Since cracking is done at pressures near atmospheric, no major



Refrigeration and distillation at various temperatures is the basis of gas separation in ethylene recovery.

compressing equipment is required for making the ethylene. The large use of compressors comes in the recovery process. The feed gas containing ethylene is compressed to about 600 psi., cooled to about 0 F. and introduced into a fractionation column where methane and hydrogen are taken in the overhead. Since the overhead gas is saturated with ethylene and ethane, refrigeration to levels as low as −140 F. is applied and the liquid obtained is returned to the tower as reflux. The residual gas consisting of methane and hydrogen can be piped away and used as fuel. The fractionating column, operating at between 500 and 600 psi. pressure, is also known as either a demethanizer or as a methane tower.

In the separation of ethylene, a series of fractionation columns is used, each operating at progressively lower pressures and progressively higher temperatures. After the methane tower, each tower has an overhead stream which is cooled sufficiently to liquefy the product to be removed. Some of the liquefied material from the overhead is returned to the column as reflux and the remainder of the liquefied material is removed as product.

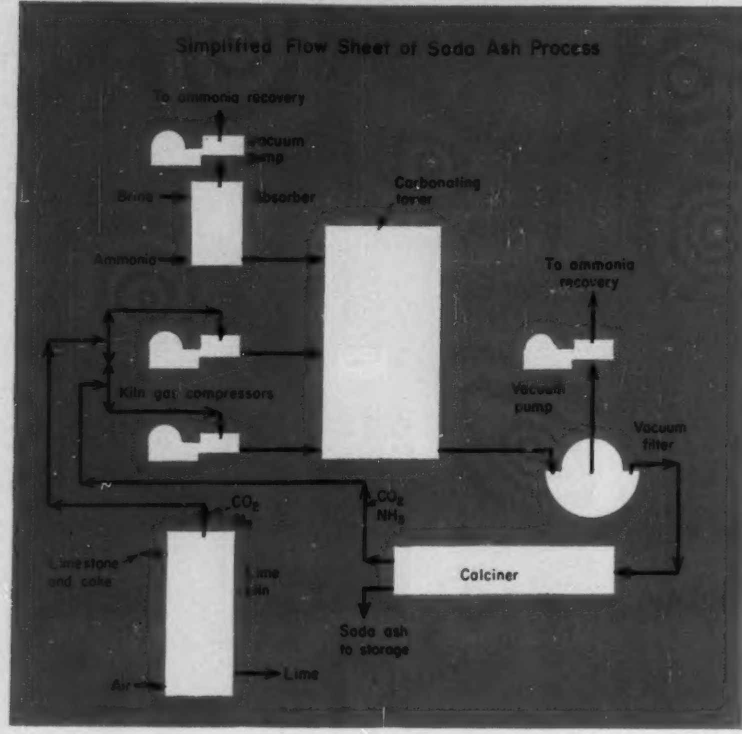
The bottoms from one column are led to the next column which operates at a lower pressure. In this manner the methane tower, operating at pressures up to 600 psi., is followed by an ethylene tower operating at around 400 psi. where ethylene is removed from the overhead as product. Bottoms from the ethylene tower go to an ethane tower operating at around 380 psi. where ethane is removed from the overhead and where the bottoms are led to a propylene tower operating at about 220 psi. Here propylene is removed from the overhead. The bottoms can be used as fuel.

In order to liquefy the overhead stream for the removal of product and to provide for reflux, a temperature level lower than that in the fractionating column must be provided. At the pressure levels mentioned above, a temperature level around 0 F. is required to liquefy ethylene, about 40 F. to liquefy ethane, and around 100 F. to liquefy propylene. The overhead from the methane tower is refrigerated to about −140 F. to recover as liquid those hydrocarbons heavier than methane. Ethylene refrigeration is used to provide the −140 F. temperature level and propane refrigeration is normally used to provide cooling for the 0 F. and 40 F. levels and for any higher levels that the regular plant cooling water cannot provide.

The propane refrigeration requires the use of compressors. Also, if liquid product ethylene is not used in the methane tower reflux condenser, and then in some further process, compressors are required in the ethylene refrigeration system. In some ethylene recovery processes other refrigerant gases such as ethane, ammonia, and propylene are used. Although the various processes operate at different pressures and remove products other than ethylene in different fractions and by different means, all of the commercial processes require some degree of feed gas or cracked gas compression and some refrigerant compression.

High-Pressure Processes

In the manufacture of urea, ammonia and carbon dioxide are charged separately to an autoclave



Soda ash production makes wide use of both compressors and vacuum pumps.

at pressures up to 3,000 psi. A compressor is used to provide the required pressure for carbon dioxide, whereas pumps may be used to handle the liquefied ammonia.

Production of chemicals by the Oxo process for the hydroformylation of olefins involves the compressing of carbon monoxide-hydrogen synthesis gas at pressures in the order of 3,000 psi. These high pressures are required in order to keep the partial pressure of carbon monoxide at a level which will prevent the decomposition of catalyst during the Oxo reaction. Octyl and nonyl alcohols and butyraldehyde are produced commercially by this process.

Hydrogen compressors employed in various hydrogenation processes, ranging from the hydrogenation of fats and oils, to the hydrogenation of coal, operate at pressures up to 6,000 psi. The handling of hydrogen and other highly flammable gases in reciprocating compressors normally requires special precautions to prevent escape to the atmosphere.

Vented packing can be used in the stuffing box at the crank end of the compressor cylinder where the piston rod enters the cylinder. A double seal housing with a second set of packing for the piston rod can be inserted between the compressor frame and the compressor cylinder. This double seal housing can also be vented. By leading the vent from the double seal and the vent from the cylinder packing box either to the compressor suction line or to a place for disposal, you can prevent any gas handled by the compressor from escaping to the room or area in which the compressor is located.

The highest pressure compressors used commercially are in plants producing polyethylene. Compressors can be used to handle ethylene at discharge pressures from 20,000 to 35,000 psi. In addition to these high-pressure polyethylene plants, newer processes allow a polyethylene type material to be produced at pressures around 500 psi., and also at pressures close to atmospheric. Almost all of the polyethylene plants operating today are of the high-pressure type. Aside from these high-pressure polyethylene compressors, the highest pressures used commercially in full-scale plants are the 15,000-psi. ammonia-synthesis-gas compressors.

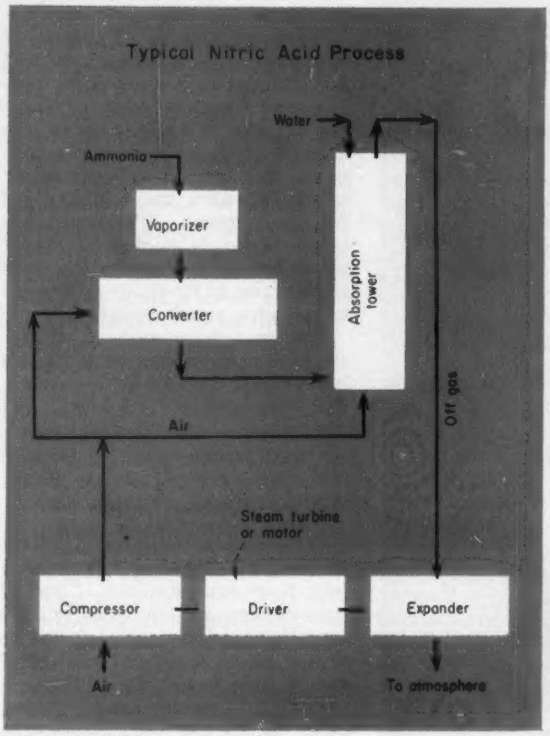
Process Refrigeration

Refrigeration, it has been noted, is an essential component of many of the processes discussed. In the low-temperature processes such as hydrogen purification, the suction pressure of gas to a compressor is usually at or above atmospheric pressure. Lower temperature levels can be reached with the same refrigerant if the compressor suction is operated at pressures below atmospheric, but you run the chance of having your refrigerant contaminated by air and moisture leaking into the system. Centrifugal compressors can take suction at low temperature levels; however, because of the problem of lubrication and the fit of mechanical moving parts in reciprocating compressors, it is desirable to heat up a cold gas to a temperature of at least −40 F. at inlet.

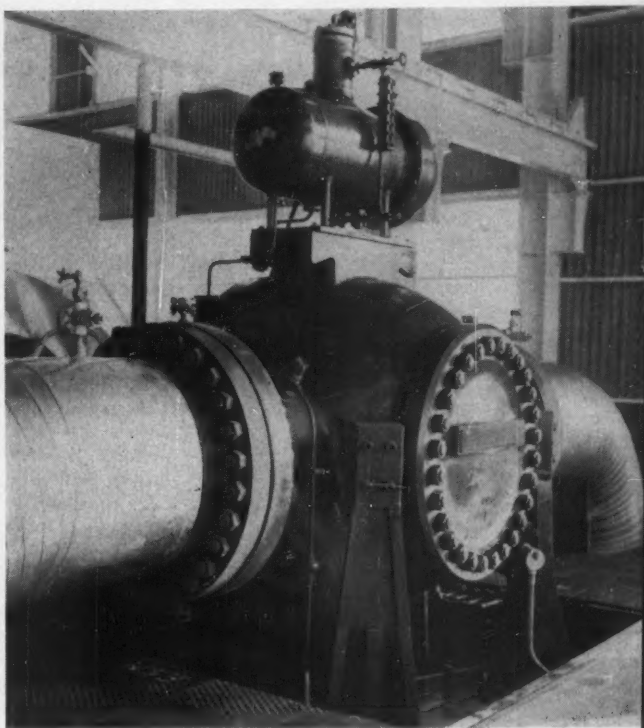
The application of compressors to process refrigeration systems requires the judicious use of interstage pressures, various types of interstage cooling, use of condensate, and balancing all three with the evaporator pressure and condenser pressure. The most economic arrangement uses standard sizes of compressors and exchangers.

Determination of the most economical pressure levels and exchanger surface requirements can only be done by trial-and-error; hence, lengthy calculations are necessary to assure that the best equipment selection is made. The more stages in the compressor selected, the more lengthy these calculations can become. In general, this results in more lengthy calculations for centrifugal compressor systems than for reciprocating compressor systems. This is true because centrifugal compressors normally require a greater number of stages for the same over-all ratio of compression.

In chemical process work, there are some places where the hydrocarbon gases and ammonia cannot be used as refrigerants because of their toxicity and flammability. In the pharmaceutical industry, the possibility of contamination due to refrigerant leakage militates against the use of hydrocarbons or ammonia in many applications. In



Expanders for power recovery find use in nitric plants.



Booster centrifugal compressor on a natural gas pipeline.

pharmaceutical and drug manufacture the various Freon gases are widely used to provide refrigeration. Freon-11 is regularly used for temperature levels down to about 15 F. and Freon-114 is in service on applications to −20 F. Freon-12 and Freon-22 are used to around −100 F.

Freon machines take suction below atmospheric pressure and compress to around 15 psig. for F-11, 40 psig. for F-114, 135 psig. for F-12 and 225 psig. for F-22. In many cases an intermediate liquid such as water or brine is used as a carrier between the refrigerant cycle and the process fluid being cooled. All of the refrigerant gas discharge pressures given are subject to fluctuation with the temperature of the cooling water available. The temperature level which can be reached with the refrigerants used is also tied in either directly or indirectly with the temperature of the cooling water used. These variations are reflected in the volume of gas handled by the compressor and the power required.

Compressors are the heart of refrigeration systems. In addition to comfort air conditioning used in offices and laboratories, the same type of compressor units are used in refrigeration systems in chemical industry to provide control of the physical properties of materials during processing, such as the control of humidity and temperature in the spinning machines and spinning rooms of acetate rayon plants. This permits spinning of physically satisfactory acetate filaments by evaporating the solvent at a constant rate and preventing water vapor from being condensed by the evaporation of solvent.

Similar type compressing equipment is used in viscose rayon plants to provide the required temperature level for controlling chemical reaction rates and storing of temperature sensitive materials. Other examples of chemical reactions requiring the removal of heat through the use of refrigerants or refrigerated liquids are found in nitration, esterification, saponification, and neutralization.

Applications of compressing equipment in air fractionation, catalytic reforming, ammonia production, ethylene recovery and process refrigeration have illustrated the use of equipment for providing either the pressure conditions needed for chemical reactions with a mixture of gases, or for the pressure conditions which allow a change of phase for refrigeration or separation. The synthetic organic chemicals industry abounds in additional examples of these types. Production of ethylene oxide from ethylene; of ethyl alcohol by direct oxidation of ethylene; of intermediates in the manufacture of glycerine, are all examples where compressors are used on a large scale. Production of intermediates and end products in processes in which acetylene is made from natural gas, and the production of oxygenated chemicals by the partial oxidation of propane and butane, are other examples.

Compressors for Inorganics

In the inorganic chemical industry one of the large uses of compressors is in making soda ash. Air blowers are used to provide air for combustion in the lime kiln

Some Reasons for Using Compressors in Process Industries

1. To provide desired pressure environment for chemical reactions.
2. To control boiling point of fluids, as in gas separations, refrigeration, evaporation.
3. To evacuate enclosed volumes.
4. To transport gases or vapors.
5. To store compressible fluids as gases or liquids under pressure; to assist in recovering them from storage or tank cars.
6. To convert mechanical to fluid energy for operating instruments, air agitation, fluidization, solids transport, blow cases, air tools and motors.

where an overhead product of carbon dioxide and nitrogen is taken off. This kiln gas is then mixed with a rich carbon dioxide-ammonia gas taken from the bicarbonate calciner.

Here the compressors are used to provide enough pressure to allow the gas to bubble up through the carbonating tower. Two pressure levels are usual—a mixture rich in carbon dioxide introduced at around 45 psig. near the bottom of the carbonating tower, and a lean gas introduced at around 25 psig. nearer the middle of the tower. The absorber where the brine is ammoniated is generally under a vacuum and a vacuum pump is used to remove the noncondensable gases.

A vacuum pump is also used to provide a vacuum on the crude bicarbonate filter. The vacuum pumps for both these services take suction in the 10 psia. range. For small capacities, rotary type compressors are used. Reciprocating compressors and vacuum pumps are found in some of the larger installations.

Dust in the kiln gases is difficult to remove and finds its way into the compressors used in these plants. The gas mixture containing carbon dioxide, ammonia and dust makes lubrication of the compressor cylinders difficult, and corrosion is also a problem. By operating the compressors at speeds slower than those of standard air compressors, using high-alloy metals in the valves, arranging cylinders with top suction and bottom discharge, providing a stainless steel piston rod, and feeding a dilute soda solution to the cylinder to help prevent an accumulation of dust, users of this equipment have been able to keep maintenance costs relatively low.

Centrifugal compressors are also in use on this lime kiln gas but their application has been limited to the larger plants.

From CO_2 to Nitric Acid

Carbon dioxide for liquid or solid CO_2 comes from many sources. Three-stage compressors are used to provide the 900 to 1,200 psi. pressure needed to liquefy the carbon dioxide prior to solidifying it. Some purification of the gas is done at the interstage levels which are roughly 80 psi. and 400 psi. Interstage purification is accomplished through the use of oil separators, scrubbers, and dryers.

In chlorine production, the chlorine is withdrawn from electrolytic cells, cooled, dried, and taken into the suction of rotary compressors of the liquid-piston type, operating with sulfuric acid as the sealing liquid. Most installations use this rotary type compressor, taking suction at less than atmospheric pressure and discharging at pressures from 15 to about 30 psig. A few reciprocating compressors are used which discharge at pressures up to 80 psig. Ammonia and Freon provide refrigeration for liquefying the chlorine for storage.

In addition to the expanders previously mentioned as used in air fractionation plants—which operate at temperatures in the neighborhood of −300 F.—we also find expanders designed for operation on hot gases up to 950 F. Some expanders are being tried on 1,250 F. gases. Most plants recently constructed for the production of nitric acid provide air at up to 120 psig. pressure. This is mixed with ammonia, passed through a catalytic converter, and the resultant gas and more air enters an absorption tower where nitric acid is formed.

Waste gas coming off the top of the tower is primarily nitrogen at pressures as low as about 80 psig. The waste gas is heated to about 900 F. and is used to drive the expander. This, in turn, is connected to a centrifugal compressor which furnishes the oxidizing air for the process. Whatever additional power is needed to supply the full amount of air for the process is made up by either an electric motor or a steam turbine.

Similar hot-gas turbine-expanders have been applied on tail gases in organic chemical processes. They are used to drive centrifugal compressors and recover power which otherwise would be wasted.

Transportation and Storage

Compression equipment has a number of other important uses including gas pipelines, liquefied gas storage, and tank-car unloading. Gas pipelines are used for the transmission of natural gas, ethylene, acetylene, and the LPG gases including propane and butane. Most natural-gas transmission-line compressors operate with 300 to 600 psi. suction pressure and 800 to 1,200 psi. discharge pressure.

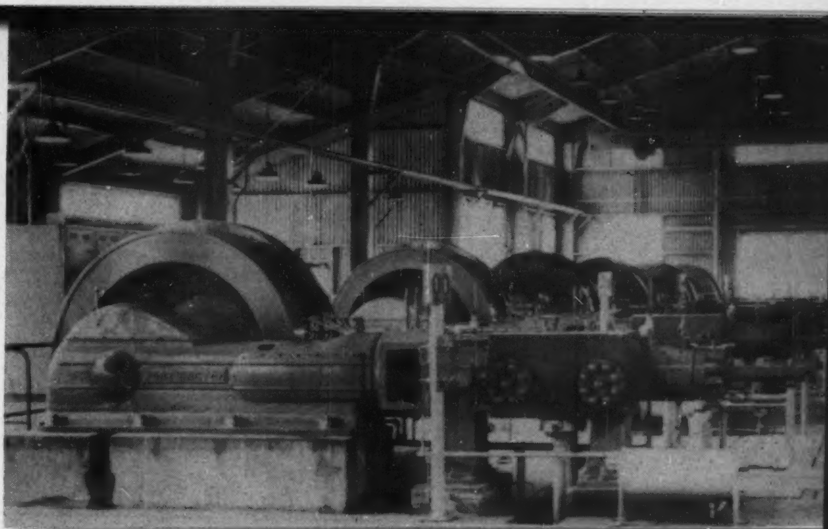
Compression equipment finds wide use in storing compressible fluids as a liquid in vessels, cylinders, tanks, tank cars, and tank trucks. Among the commercially important gases requiring the use of compression equipment for storage are acetylene, air, ammonia, butadiene, butane, isobutane, butylene, carbon dioxide, chlorine, ethylene, Freon-12, Freon-22, helium, hydrogen, hydrogen chloride, hydrogen sulfide, methyl chloride, nitrogen, nitrous oxide, oxygen, propane, propylene, and SO_2.

Tank car unloading compressors are common in unloading ammonia, propane, butane, butadiene, styrene, sulfur dioxide and other volatile liquids from tank cars. These compressors in many cases pay for themselves solely from the extra amount of gas removed by evacuating residual vapor left in tank cars after being emptied of liquid.

Vacuum Pumps

Vacuum producers of many types ranging from diffusion pumps, to reciprocating vacuum pumps, are in use. Many chemical industry evacuations are accomplished by the use

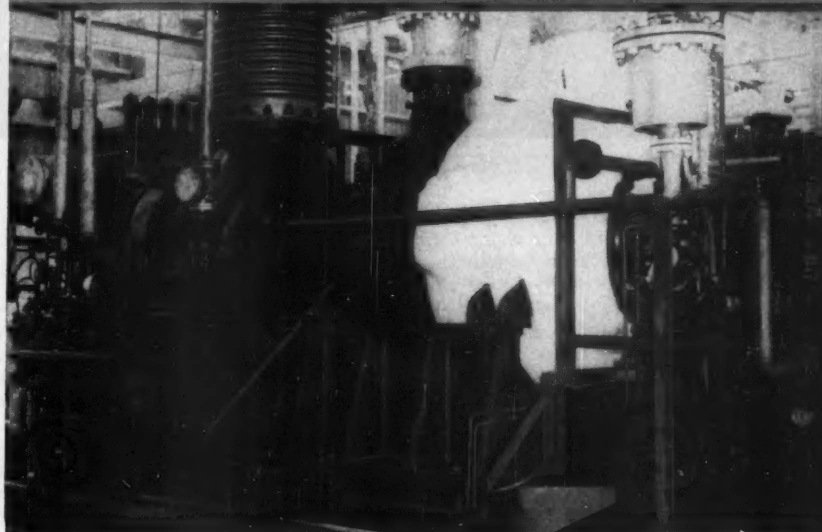
of steam jet ejectors. These ejectors can furnish any required vacuum down to an absolute pressure of about 50 microns (0.050 mm. Hg). For lower vacuums a mechanical high-vacuum pump or such a pump plus a diffusion pump is commonly used. The lowest practical limit for standard reciprocating vacuum pumps is 1.0 in. Hg abs., whereas rotary vacuum pumps are normally limited to around 6 in. Hg abs. for single-stage units. Two-stage vacuum pump units can get down to about 0.3 in. Hg abs. on blank suction.



Six recirculator compressors handle recycle gas for synthetic ammonia.

Trends in Compression

Since the end of World War II the volume of product handled in single chemical process units has approached the order of magnitude of oil refining industry practice. This has resulted in the economic application of centrifugal compressors instead of reciprocating units in a number of installations. This trend toward large units is evident in some of the recently built ethylene plants, ammonia plants, acetylene plants, and soda ash plant expansions. Large volume does not automatically mean that centrifugal units are favored over reciprocating units but it does mean that consideration must be given to both types if an economical result is to be obtained.

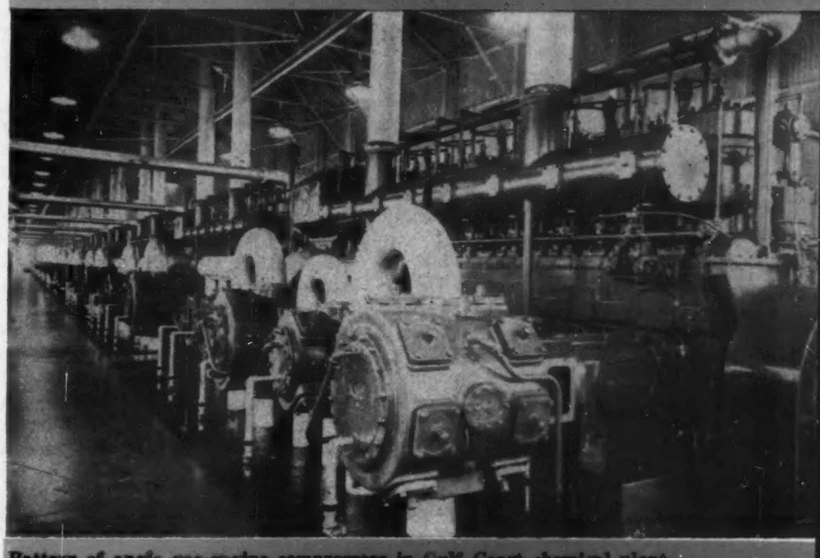


Turbine-drive centrifugal compressor handles ethane in ethylene recovery.

Numerous large-scale plants are still being built using reciprocating equipment. A delicate balance appears to be involved between the advantage of smaller floor space and presumably lower maintenance costs obtained with centrifugal units; and the capacity and pressure flexibility inherent in reciprocating units.

In general, reciprocating compressors have an edge pricewise for handling compressible fluids at capacities up to 10,000 cfm. The chart listing general areas of compressor application, if used in conjunction with the tabulation of general limits of compressors and vacuum pumps, gives a reasonably accurate indication of the types of compressing equipment which may be considered preliminarily.

As a rough rule of thumb for process applications, a preliminary comparison of centrifugal machines with reciprocating units is desirable if the volume of a gas stream at the pressure leaving the compressor is over 600 cfm.



Battery of angle gas-engine compressors in Gulf Coast chemical plant.

FACTORS THAT INFLUENCE

Selection of a Compressor

Many are the arguments that can be raised in favor of various compressors. In the final analysis, economic factors will govern your selection. Here, in proper perspective, are factors you must weigh before choosing between positive displacement and dynamic machines.

William T. Alderson

Most chemical reactions take place more rapidly if the elements are under pressure—hence the wide use of compressors in the chemical and process industries. Since the compressor is so important in the process and, aside from utilities, may indeed be the only piece of equipment with moving parts, it should be selected most carefully.

Proper selection should always stand the test of economics. This is not possible unless both the compressor manufacturer and the user have full knowledge of all the conditions and factors governing selection. The intent of this article is to enumerate and discuss the importance of those factors, based on the experience of the compressor manufacturer.

Compressors may be divided into two classes: the positive displacement type and the dynamic type. In the positive displacement class the reciprocating compressor is the best known and most widely used. Its counterpart in the dynamic category is the centrifugal compressor. Herein, our discussion will center around selection factors related to these two machines as leading units in these categories.

In some instances, certain factors dictate the use of one or the other machine, without question. In other cases all factors must be analyzed carefully in order to make a choice between the two types.

GAS PROPERTIES

Gas Analysis

In the selection of any compressor the starting point should be a complete and accurate description of the gas to be compressed. This is relatively simple if we have a pure, homogeneous gas such as H_2, N_2, CO_2 or NH_3. In the case of composite gases, however, the correct percentages of the component gases plus any entrainment of liquids or solids must be reported very accurately.

The gas composition is arrived at usually by analyzing the process. Presence of contaminants is known about because of experience with similar processes at some earlier date.

The successful operation of a compressor depends greatly upon the reliability and thoroughness with which the gas is described to the compressor manufacturer. Many compressor troubles can be traced directly to elements or contaminants in the gas which were not reported initially and for which no provision was made in the design of the compressor, or in the installation.

Gas analysis normally is stated in percent by volume which is synonymous with mole percent. One mole volume of any perfect gas measured at 14.7 psia. and 60 F. is equal to 379 cu. ft. The weight of this volume in pounds is numerically equal to the molecular weight of the gas in question.

The gas analysis is normally reported on the basis of dry gas. If the gas is partially or fully saturated with water vapor this should be reported also. From the gas analysis the average molecular weight, average compressibility, and the ratio of specific heats (c_p/c_v) is determined.

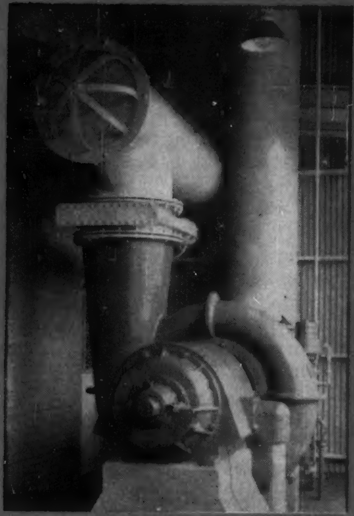
Molecular Weight

The molecular weight of a gas influences the type, design and performance of all compressors. At standard conditions of temperature and pressure, gas density is proportional to molecular weight.

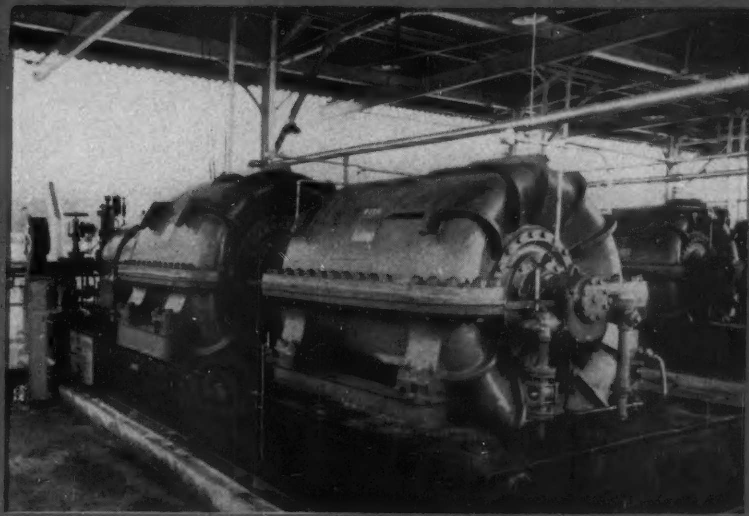
Since the density or weight of a gas varies with temperature, we shall use the term gravity or gas density synonymously with molecular weight for convenience. Let us examine the effect of gravity, or density on the two classes of compressors.

Except for some change in efficiency due to valve losses, the reciprocating compressor is not affected by the molecular weight of the gas. Periodic changes in gas composition and density will have little influence.

A reciprocating compressor handling a low density gas such as



For 5-psi. air compression, single-stage centrifugal does job. (Fig. 1)



An equal volume (15,000 cfm.) of hydrogen could only be compressed to the same pressure if the centrifugal had a number of stages in two casings. (Fig. 2)

hydrogen can operate with much higher valve velocities than when handling a high density gas such as Freon. The reason is that valve losses, a major factor in calculating compression efficiency, vary as the square of the velocity and directly as the density of the gas.

Because of its basic concept, the centrifugal compressor can compress a high density gas more easily than a low density gas. How gas density affects performance of a centrifugal compressor is explained simply by likening a single molecule of hydrogen to a ping-pong ball and a single molecule of Freon to a golf ball, both of the same diameter.

If each ball is attached in turn to a string of a given length, and is twirled about a fixed axis at a given velocity the tension in the string will be much greater when holding the golf ball than when holding the ping-pong ball. This tension corresponds to the pressure which is generated at the periphery of a single-stage wheel of a centrifugal compressor. Obviously, for equal peripheral speeds it will take many stages compressing hydrogen to equal the pressure created by a single stage compressing denser Freon.

From this simple analogy you can see that, other things being equal, the lower the gas density the more complex and costly is the centrifugal. This can be emphasized further by considering a centrifugal compressor to compress 15,000 cfm. of gas from 14.7 psia. to 19.7 psia. If the gas is air it will be a simple single-wheel centrifugal as illustrated in Fig. 1.

Now should the gas be hydrogen it will require a multi-stage centrifugal, probably in two casings as illustrated in Fig. 2. The hydrogen compressor, without the driver, would cost about eight times more than the air compressor.

The influence of molecular weight or specific gravity on compressor selection can be illustrated in the refrigeration industry where the single-casing centrifugal compresses large volumes of Freon for high-tonnage refrigeration. An equal amount of refrigeration using low molecular weight ammonia would require a multiple-casing centrifugal or a very large reciprocating machine.

If the percentage of constituents in a composite gas varies from time to time so will the molecular weight and gravity. A centrifugal compressor to generate the desired pressure when handling the full flow of such a gas would have to be designed for the lowest expected molecular weight or density. Excess pressure resulting from increased molecular weight would have to be reduced by throttling, change in speed, or by some other means.

Ratio of Specific Heats

The adiabatic compression exponent, k,* which in a perfect gas is equal to the ratio of specific heats (c_p/c_v), is very important in the selection of a compressor. It is essential for calculating the theoretical horsepower and the temperatures which result from heat of compression.

Temperatures are important in a reciprocating compressor. High temperatures affect the lubricating qualities of oils and cause them to decompose, thus introducing elements into processes which may be very undesirable or dangerous. Consequently, a greater number of stages may be used to hold temperatures per stage within desired limits, even though the additional stages may have little or no effect on horsepower.

Theoretically, a gas with low k value can be compressed with much higher ratios of compression per stage, yet still hold temperatures within desired limits. Unfortu-

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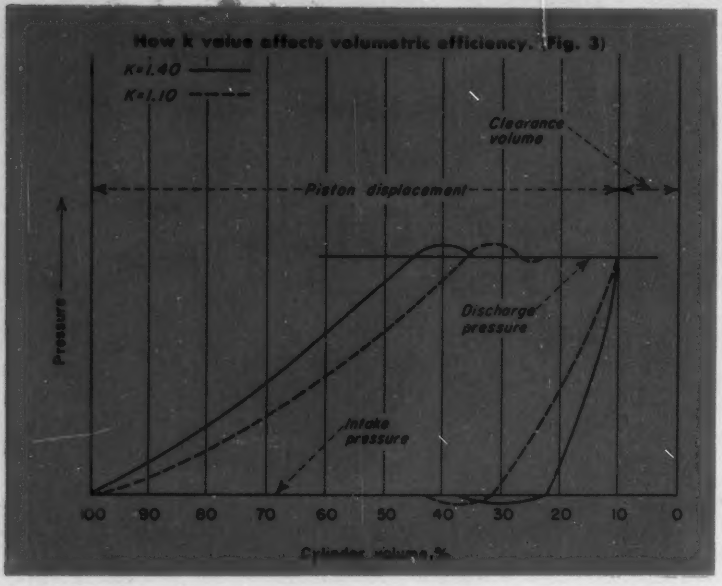
*Normally k varies between 1.67 for the monatomic gases, through 1.4 for diatomic gases and 1.33 for polyatomic gases, to 1.1 for high molecular weight organics. However, the exact value is affected by temperature and pressure. Furthermore, while the k value is used in the calculation of theoretical adiabatic compressions, in actual compressions a polytropic exponent n must be substituded for k, which serves to express one measure of the imperfection of the actual process as compared with the theoretical. The polytropic exponent n will always have a higher value than k in any given compression.—*Editor.*



How k value affects volumetric efficiency. (Fig. 3)

nately, full advantage cannot be taken of this factor. The same characteristic which affects temperature also affects volumetric efficiency. With normal cylinder clearances it may become uneconomic to compress to high ratios because of the great reduction in volumetric efficiency. Fig. 3 will illustrate how the *k* value affects volumetric efficiency of a typical reciprocating compressor.

In a centrifugal compressor the ratio of specific heats (*k* value) has marked influence on the design for the following reasons.

Assume that a single wheel compresses alternately two gases of equal density, one having a *k* factor of 1.1, the other a *k* factor of 1.4. As compression takes place temperature increases less for the gas with the 1.1 *k* factor than for the gas with the 1.4 *k* factor. Consequently, the average density or specific gravity of the low *k*-factor gas will diminish less than that of the high *k*-factor gas. The result is that the pressure generated by the single wheel under these identical conditions of peripheral speed and volume at inlet will be less for the high *k*-value gas than for the low *k*-value gas.

Compressibility

Compressibility is a term used to describe the deviation of a gas from the perfect gas laws and is a very important factor in the design of all high-pressure compressors. Reduced to its simplest terms the volume of gas to be handled by each stage of compression, be it reciprocating or centrifugal, is equal to the volume calculated by the perfect gas laws multiplied by the compressibility factor, Z, at the particular pressure and temperature conditions.

In the case of either a single-stage reciprocator or a single-stage centrifugal, the design problems resulting from compressibility of a gas are relatively simple. The volume to be handled by this single stage can be accurately calculated at suction conditions.

On multi-stage reciprocators and centrifugals, the volumes must be calculated for each succeeding stage. If the volumes are calculated incorrectly the interstage pressures will be higher or lower according to the margin of error. In this manner, compressibility affects the proper proportioning of each stage of a centrifugal and the piston displacement of each stage of a reciprocating compressor.

Moisture Content

The moisture content of any gas is very important in the selection and design of a compressor. Let us assume that a given quantity of air, pounds per minute or second, is required to supply oxygen for a process. The quantity of air is usually stated as dry air.

Under normal atmospheric conditions at sea level there is no such thing as dry air. There is always some moisture content and this relative humidity changes the specific volume of the air. Thus at the same temperature and pressure, the specific volume increases with a rise in the relative humidity so that more total volume of gas must be handled in compressing a pound of air.

Unless the compressor, be it reciprocating or centrifugal, is designed for an intake volume that compensates for the relative humidity the desired quantity of dry air or oxygen will not be obtained for the process. Each stage of a reciprocating or centrifugal compressor must, therefore, be designed to handle the volume of air or gas coming to that stage. And that volume must be more than the volume of the dry gas in proportion to the moisture content.

Moisture in gases may be water vapor, as in the case of a gas which has passed through a water scrubber, or it may be other condensibles related to the gas being handled. In either case moisture content of any gas must be taken into consideration in the selection and design of a compressor.

Corrosiveness

It is obviously important to know if any corrosive elements are present in a gas. This information should be both qualitative and quantitative.

Corrosive elements are important in selecting construction materials for both reciprocating and centrifugal compressors, design and construction materials of seals for centrifugal compressors and lubricants for reciprocating compressors. Even slight corrosion can produce corrosion fatigue and failure of parts in either type of compressor when these parts are subject to high cyclic stresses.

Contaminants

A great many compressors serving the chemical and process industries must handle gases which contain various contaminants. Often the seriousness of these

contaminants is not recognized until the machines are installed and operating. If the operator has had previous experience with such contaminants he should warn the designer of their presence.

A contaminant could be reported in the gas analysis in trace amounts. Even minute quantities of substances such as sulfur compounds and chlorides can cause corrosion or other mechanical difficulties. Contaminants may be particles or slugs of water, particles of catalyst in refinery units, solids which are formed from gas constituents under process conditions of pressure and temperature, or that originate from many other sources.

In a reciprocating compressor abrasive solids may cause wear of valves, pistons, rings, cylinder bores, packing and piston rods, all of which result in high maintenance. Solids passing through a centrifugal compressor can erode impellers and casings severely. Contaminants of this nature can and should be removed from the gas stream before the gas reaches the compressor.

The compressor industry, in applying air compressors for air power in industrial plants has long recognized the effect of contaminants in atmospheric air, be they dirt, sand or corrosive fumes from chemical processes. Use of efficient filters and the proper location of compressor intake connections has largely eliminated the troubles which can result from these conditions.

Limiting Conditions

In the selection and design of a compressor it is important to know of any limiting temperature or pressure conditions. For example, in the compression of dry chlorine gas, whether in a carbon-ring reciprocating compressor or in a centrifugal machine, the temperatures should be kept below approximately 250 F. Otherwise, the chlorine will become chemically active and, in the presence of iron or steel, ferric chloride will form readily.

In oil-lubricated compressors handling air for oxygen plants, experience indicates that theoretical temperatures per stage should not exceed approximately 330 F. Above this temperature some of the lubricating oil will crack releasing hydrocarbon derivatives which are difficult to remove from the air. However, if not removed they will create a serious hazard in oxygen columns.

Some gases become very unstable under high-temperature conditions. Therefore, it is important that the effect of temperature and pressure on any gas be stated clearly.

All of the foregoing factors affect the selection and design of a compressor. A compressor, either reciprocating or centrifugal, is purchased for one thing only, i.e., to handle a compression problem. The end result is what counts. But the end result cannot be reached to the highest degree unless all factors are known and the compressor selected and designed accordingly.

PROCESS CONDITIONS

Data which are established by the process affect the selection and operation of the compressor. It should be possible to develop the process conditions on either a calculated basis or a reasonable assumption. Sources of such information are flow sheets, calculated chemical requirements, previous installations, and various other methods used by chemists and chemical engineers to develop the data for a complete chemical process.

We will take up the various conditions established by process requirements and explain how they affect selection of the most suitable compressor.

Flow Rate

In any compression problem it is obvious that for a given compression ratio the flow rate to be handled establishes the physical size of the equipment under consideration. Flow rate of a gas can be expressed in several ways: million cu. ft. per day; standard cu. ft. per minute; cfm. referred to intake conditions; pounds per hour; pounds per minute; moles per hour, etc. All units should be identified properly so that conversion can be made readily from one terminology to another.

The flow rate definitely influences selection. If 100,000 cfm. of gas must be compressed at near-atmospheric suction conditions, a centrifugal compressor almost certainly would be used for the lower stages of compression. If the final discharge pressure is quite high, for example 5,000 psi., the upper stages of compression would be handled by reciprocating compressors.

Where the centrifugal leaves off and the reciprocating compressor takes up the job would depend upon the gas density, type of regulation required, etc. If, on the other hand, 100 cfm. of gas must be compressed to 5,000 psi. discharge pressure a reciprocating compressor would most certainly be used for the whole range.

These extremes are mentioned as examples only and indicate that the quantity of gas being handled is significant in selecting the type of compressor.

The variation in flow rate from maximum to minimum can likewise affect the selection. If the process requires a change in flow rate from the maximum down to or near zero, the reciprocating compressor can do it with a reasonable sustained efficiency. It is done by clearance pockets, suction valve lifters, or speed change in the case of a reciprocating steam-engine drive.

With the centrifugal compressor, operation cannot be obtained below the pumping point which ordinarily is between 50 and 75% of rated capacity. Therefore, when you give a compression problem to a compressor manufacturer you should include the complete range of expected capacity and pressure conditions to assure selection of the proper compressor.

Temperature

The temperature of a gas coming to a compressor must be known for several reasons. If the quantity of gas or flow rate is given in terms of some standard conditions you must know the actual inlet temperature. Then the capacity can be corrected, referred to intake conditions at the compressor.

Incidentally, in both reciprocating and centrifugal machines the compressor recognizes only capacity at the actual inlet conditions. Therefore, compressors are rated in these terms.

The actual conditions can be converted to standard conditions for reference so long as you keep

in mind that conditions at the compressor intake are the only ones that the compressor can actually recognize.

Each type of compressor has some practical limits as to the maximum or minimum gas temperatures that can be handled. For example, the centrifugal compressor has been used quite successfully as a hot gas circulator to compress and recirculate gas at temperatures as high as 800 F. With our present known lubricants, such temperatures are impractical if not completely impossible in a reciprocating compressor.

If the flow rates are too low to be practical for the centrifugal compressor and the reciprocating compressor must be fitted into the process it can be done only by cooling, compressing and reheating the gas.

Reciprocating compressors are being operated successfully with suction temperatures below minus 100 F., but these low suction temperatures again create a lubrication problem. Insofar as mechanical operation is concerned, the centrifugal compressor is less affected by high or low temperature extremes than is the reciprocating type compressor.

Hydraulically, the centrifugal compressor is affected much more by temperature than is the reciprocating machine. For example, a centrifugal compressor designed for a given capacity and pressure with 70 F. inlet air would not deliver the desired pressure if the suction temperature were increased to 100 F. (a decrease in density).

Conversely, it would deliver excess pressure if the temperature of the air at suction were reduced to 30 F. (an increase in density). Consequently, the centrifugal compressor must be designed to deliver the desired capacity and pressure under the maximum inlet temperature conditions.

Gas temperature at the inlet of any stage of reciprocating compressors is important. It affects horsepower, capacity and final discharge temperature of that particular stage. Lubrication may be affected by discharge temperature.

Inlet and Discharge Pressure

Inlet and discharge pressures are very important in a compression problem, yet when they vary the magnitude of the effect is seldom realized.

On reciprocating compressors, particularly multi-stage machines, the most common error is to assume that a small change in suction pressure makes very little difference. It must be remembered that once a multi-stage reciprocating compressor is proportioned, lowering the suction pressure while maintaining the discharge pressure, will lower the over-all horsepower, lower the differential pressure on all stages except the last stage, increase the differential on the last stage and very often the horsepower of the last stage.

Conversely, if we raise the suction pressure to the first stage we raise the horsepower of the complete machine, raise the differential in pressure on all stages up to the last stage, lower the differential on the last stage and probably lower its horsepower.

If a 6-stage compressor designed for 15 psia. intake and 5,000 psi. discharge had the suction pressure raised to 20 psia. the increase in horsepower would be approximately 25%. All intercooler pressures would exceed the design point and cause safety valves to blow.

In centrifugal compressors, if the suction pressure is raised the discharge pressure will exceed the design point, the horsepower will increase, and excess pressure will have to be throttled out. If the suction pressure is lowered, the centrifugal will not compress to the desired discharge pressure. Therefore, it is most important to the compressor manufacturer and to the user that the suction and discharge pressures be established accurately.

Discharge pressures have considerable bearing on the selection of the type of compressor. Centrifugal compressors in high horsepower ranges are now operating at pressures above 2,000 psi. This is an exceptional application, however.

Low compression ratios with reasonable capacities favor the centrifugal, whereas, high compression ratios and higher pressures favor the reciprocating machine. One couldn't attempt to define the borderline in pressure between reciprocating and centrifugal compressors because there are too many other factors to be considered when making the choice.

Interstage Pressure

In some multi-stage process compressors the interstage pressure is set by the process. This may be for washing out undesirable elements, adding gas, or for carrying out chemical reactions which change the nature of the gas.

It is very important that these interstage pressures be stated in very definite terms. Also, it is important that the process engineer determine and state the permissible variation of these pressures to give the compressor manufacturer more flexibility in the design of the compressor.

A good example of an interstage pressure being held for washout is in some synthetic ammonia plants where CO_2 is present with the nitrogen and hydrogen in the initial stages of compression but is removed before going through the final stages. An example of gas being added is in dry ice plants where flash-back gas is injected between stages and recompressed to process pressure.

Heat Balance

This is an item which comes from the process itself and generally speaking does not directly affect the compressor but does have a bearing on the selection of the driver.

To illustrate, let us assume that a large chemical plant requires a certain quantity of exhaust steam to reach a proper heat balance. At the same time, this plant may want compressed air to be used either in process or for some fixed application within the plant.

The rest of the compressor equipment in the plant may be electric driven but the requirement for both exhaust steam and compressed air dictate the use of a steam-driven compressor. This might be either a turbine-driven centrifugal if within the centrifugal capacity and pressure range, a steam-engine-driven reciprocating compressor, or a steam-turbine-driven reciprocating compressor. The final selection depends upon many factors all of which must be considered.

Another example is found in the ammonia oxidation process for nitric acid where waste gas available under considerable pressure can be used to drive power-recovery tur-

Typical Compressor Comparison (Fig. 4)

bines, thereby, materially reducing the power from other sources.

Generally speaking, if choice of driver is dictated by the available source of power, the heat balance, waste gas or any other factors in the plant or process, that compressor which best fits the driver should receive first consideration. In other words, the centrifugal always receives first consideration if for any reason the driver must be a turbine. The reciprocating compressor should probably always receive first consideration if driver is to be an electric motor. Reason is that the majority of motor-driven reciprocating compressors can be direct driven, whereas, most motor-driven centrifugal compressors require a speed-increasing gear.

Flowsheet

The compressor manufacturer also can select and apply a compressor better if a general flowsheet of the process can be provided. Then there can be a complete understanding of the function of the compressor in the process.

Soil and Foundation

Soil and foundation conditions must be considered in the selection of a compressor and, in some instances, this dictates the type of machine. A centrifugal compressor operates without producing unbalanced forces. The foundation need be sufficient only to support the dead-weight load but with adequate stiffness to maintain alignment. Naturally, for a centrifugal compressor less foundation mass will be needed on good soil than on poor soil.

The reciprocating compressor, regardless of type, has certain unbalanced forces, couples, etc., which have to be taken into consideration. In the majority of plant locations if the soil will support a modern chemical plant there will be little difficulty installing foundations adequate for the reciprocating compressor.

The type of reciprocating compressor most widely applied today in chemical and process plants is designed specifically for a minimum of unbalanced forces. Generally, a foundation which will support the deadweight load of the compressor and maintain alignment of the compressor and driver will have adequate mass to absorb the small unbalanced forces that may be present.

Operating Expense of Transmission Station Compressor Equipment, 1952—Table 1

Company	Total Compressor Hp.	Total Maintenance Expense of Station Equipment, Dollars	One Year Maintenance Expense/Hp.
Mich. Wisconsin Pipeline Co.	139,200	504,156	$3.62
Hope Natural Gas Co.	130,745	750,432	5.74
El Paso Natural Gas Co.	206,880	584,387	2.82
Cities Service Gas Co.	140,620	526,099	3.74
Mississippi River Fuel Corp.	104,975	294,389	2.80
Natural Gas Pipe Line Co. of America	154,000	420,476	2.73
Northern Natural Gas Co.	241,920	924,919	3.82
Panhandle Eastern Pipe Line Co.	269,280	854,180	3.17
Southern Natural Gas Co.	135,220	249,118	1.84
Tenn. Gas Transmission Co.	471,820	1,344,113	2.85
United Gas Pipe Line Co.	128,700	230,119	1.79
Penn. Gas Co.	12,091	53,246	4.40
Pacific Gas & Elect. Co.	51,670	182,754	3.54
Lone Star Gas Co.	40,670	182,133	4.48
Equitable Gas Co.	26,995	76,201	2.82
Atlantic Seaboard Corp.	20,000	63,663	3.18

Note: Federal Power Commission statistics for natural gas companies, 1952.

If there is a bad soil condition, however, it is important that the compressor manufacturer know about this condition when selecting the compressor, whether centrifugal or reciprocating.

FINAL SELECTION

In recent years there has been much debate on the merits of the centrifugal vs. the reciprocating compressor. It has been stated that the centrifugal compressor is invading the reciprocating field, implying that they are competitors. The writer takes an entirely different view. The reciprocating and centrifugal compressors are not competitors, they complement each other.

The tremendous expansion in the process and other industries during recent years has resulted in some rather amazing applications of both reciprocating and centrifugal compressors, as measured by our knowledge and experience of 20 years ago.

Some compression problems have been presented which would have been economically impossible to solve without the centrifugal compressor. Other compression problems have been solved best by a combination of the two machines. Still other problems can only be solved with reciprocating compressors.

Therefore, within the limitations of their respective designs choice between a centrifugal compressor or a reciprocating compressor becomes a question of economics. The factors, of course, are first cost, installation cost, source of power, type of driver, maintenance, availability, etc. Many of these have been discussed in the foregoing.

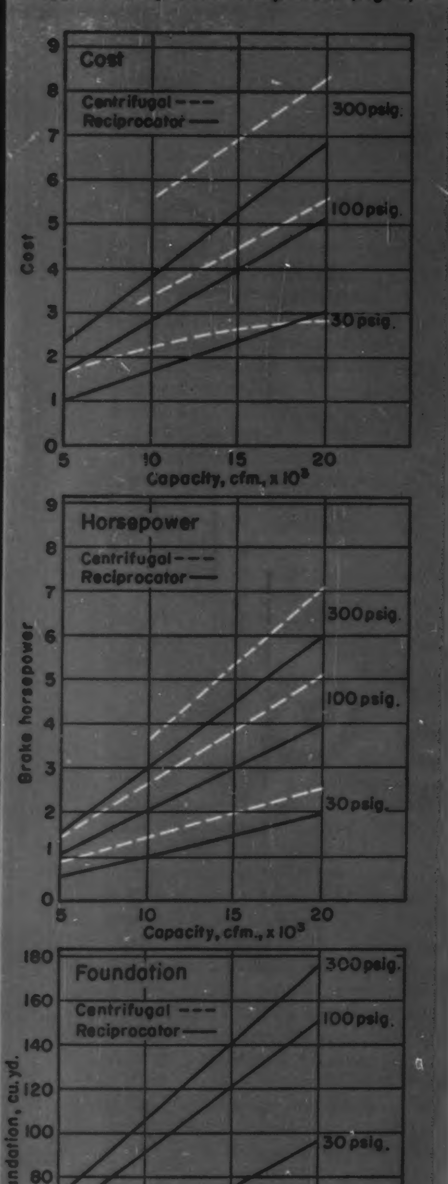
Engineers are trained basically to be factual. But being human, they are guilty at times of wishful thinking, or use of generalized information or wrong opinions to justify a decision.

The unusual interest in the centrifugal compressor is quite understandable. It is newer in concept and the engineer's inherent desire for rotary motion is here to stay. The centrifugal compressor needs no false assumptions to justify its place, nor do the manufacturers of centrifugal compressors wish to be pushed into applications which are basically unsound.

Maintenance

The most outstanding misconceptions among engineers evaluating reciprocating vs. centrifugal compressors are that maintenance is high on a reciprocating compressor (false) and that the availability of a reciprocating compressor is low (false).

Typical Compressor Comparison (Fig. 4)



It is generally conceded that when a centrifugal compressor and a reciprocating compressor handle identically the same gas, under exactly the same terminal pressure conditions on the same application, maintenance will be less on the centrifugal compressor than on the reciprocating compressor. As compression problems become more difficult maintenance on both machines increases and probably becomes more nearly equal. However, within its range the centrifugal should always show less maintenance than the reciprocator.

It must not be overlooked that the designers of reciprocating compressors have not been idle. The threat of the centrifugal has not been nearly so serious as the threat from other manufacturers of reciprocating compressors. Each manufacturer has, therefore, tried to improve his product and the modern reciprocating compressor is a very reliable machine. Just how reliable is shown by specific operating records.

Within recent years we have found some engineers evaluating maintenance on reciprocating compressors as high as $12/hp./year, and in one case up to $22/hp./year. This latter figure on the face of it is ridiculous, but what are the facts?

Probably the most rugged service for any heavy-duty reciprocating compressor is that of a gas-engine-driven compressor on natural gas pipelines. Fortunately, this is an application on which facts are available.

All natural gas pipelines in the U. S. operate under the jurisdiction of the Federal Power Commission and yearly statistical data are published for all these pipelines. It is on these data that the income of the pipeline is based.

The total cost of operating a pipeline is broken down into its various elements, including the maintenance of the compressor pumping stations. Pumping station maintenance is given in Table I.

The total maintenance cost of all compressor stations for all pipelines divided by the total installed horsepower gives an average maintenance figure of $3.18/hp./year. Naturally, most of the maintenance cost is chargeable directly to the engine-driven compressors. But there is miscellaneous equipment that requires some maintenance. So it is fair to assume that the average maintenance chargeable to the complete engine-driven compressor would be $3/hp./year.

The ratio of power-end maintenance to the compressing-end maintenance can be rated conservatively at 5 to 1. On this basis the average power-end maintenance is $2.50/hp./year and the compressing-end maintenance 50¢/hp./-year.

In the modern motor-driven reciprocating compressor frame-and-running-gear maintenance is practically nil. For the sake of argument a fair figure to charge for maintenance against motor-driven reciprocating compressors is double that of the air end, or $1/hp./year.

This we believe to be an outside figure in any well-kept and intelligently operated plant. It is a long way from the $12 figure that we found one engineer had adopted. No machinery will withstand deliberate abuse and only such treatment or outright neglect could produce costs in the $12 range.

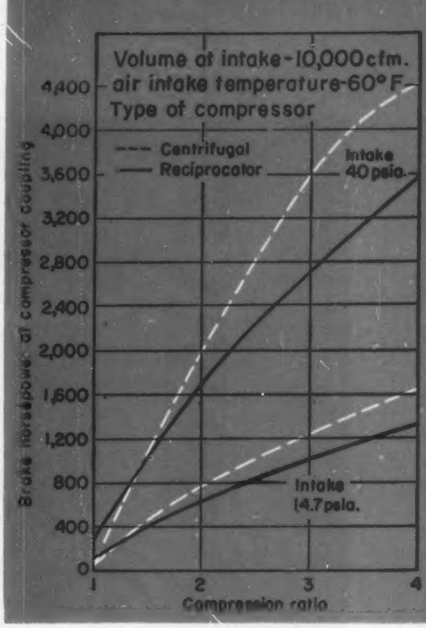
To substantiate the foregoing maintenance figure of $1/hp./year accurate records are presented for a compressor installation in a large manufacturing plant. This installation is composed of five compressors totaling 4,450 hp. which were installed in 1929. These compressors have operated from 1929 to date an average 16 hr./day, 300 days/-year, except from 1940 to 1946 when they operated 24 hr./day, 300 days/year.

From carefully kept records the maintenance cost per year over the last five years of operation was $3,-300 per year. It should be emphasized that this record is for machines which today are 25 years old. This maintenance consisted of $300 for parts and $3,500 for labor, indicating that replacement parts on compressors are at a minimum after 25 years of operating and that the maintenance cost is well under the $1/hp./year.

This plant is operated with two men per shift. There are many other plants in this country which could equal this record.

Availability of Reciprocators

The availability of the compressor in any process plant is very important. The plant is built to turn out a product. Loss of product during down time is often more



Typical Horsepower Comparison (Fig. 5)

important than the cost of repairs. Here are some availability figures taken from the record.

Plant A—A 15,000 psi. synthetic ammonia plant. The availability factor is better than 98½% since it was put on stream about five years ago.

Plant B—Three 1,750 hp. synchronous-motor-driven air compressors in a large industrial plant. No forced shutdown in three years of operation. Compressor valves are cleaned once a year.

Plant C—A 125 hp. two-stage air compressor ran 30,000 hr. without a valve failure and 60,000 hr. without a bearing failure or adjustment.

Plant D—Seventeen 2,000 hp. gas-engine-driven compressors, three-stage machines with a total of 784 valves, ran six months with only two valve failures.

Many other examples could be offered but the point to emphasize is that the modern reciprocating compressor is a highly reliable piece of equipment. When we evaluate the centrifugal vs. the reciprocating compressor, factors other than maintenance and availability should be considered in making the choice for a given job. Most of these factors we have discussed previously, except first cost and power cost.

First Cost

There is no formula for establishing the relative cost of the centrifugal compressor vs. the reciprocating compressor. As has already been established, if volume, pressure, *k* factor and all other factors are the same then gas density can influence greatly the cost of the centrifugal but have little effect on the reciprocator. For a comparison it is, therefore, necessary to select one gas.

Fig. 4 gives the relative cost of the reciprocator vs. the centrifugal motor-driven air compressor, complete with driver, at three different discharge pressure levels with atmospheric intake of 14.7 psia. Shown also are the relative floor space requirements and cubic feet of foundation.

Since lower gravity gases have little or no effect on the reciprocator but do have a decided effect on the centrifugal, the comparison will be less favorable to the centrifugal as gas gravity is reduced.

If the source of power is steam instead of electricity, the comparison is more favorable to the centrifugal because the drive is direct from the turbine. The reciprocator must have either a steam engine drive or turbine gear drive, both of which are more costly than direct-coupled turbine or electric motor.

Power Cost

The cost of power, regardless of the source, is always an important consideration in the selection of a compressor. Except at very low ratios of compression, the centrifugal compressor is inherently less efficient than the reciprocating compressor.

Fig. 5 illustrates the relationship in compressors rated 10,000 cfm. at intake. In one case the intake is atmosphere at 14.7 psia. and in the other case the intake is at 40 psia. When the centrifugal is selected the higher horsepower must be offset by lower installed cost or other application advantages.

It can be repeated that very large volumes, low ratios of compression, and low final pressures favor the centrifugal compressor. No one today would think of using the reciprocating compressor for blast furnace blowing. Conversely, higher ratios of compression, higher terminal pressures favor the reciprocating compressor. The highest pressure centrifugal to date operates at conditions comparable to those of a very moderate pressure reciprocator.

Reciprocating compressors for pressures as high as 5,000-6,000 psi. are considered as medium pressure machines. They are operated at normal rotative and piston speeds, and have maintenance and availability comparable to that of the 100 psi. two-stage air compressor. Reciprocating compressors have been built for pressures as high as 35,000 psi.

As capacities increase along with pressures, a combination of centrifugals and reciprocators may prove to be the best solution with the centrifugal handling the gas at the lower pressures to eliminate very large cylinders and the reciprocator taking the gas on up to the higher pressures.

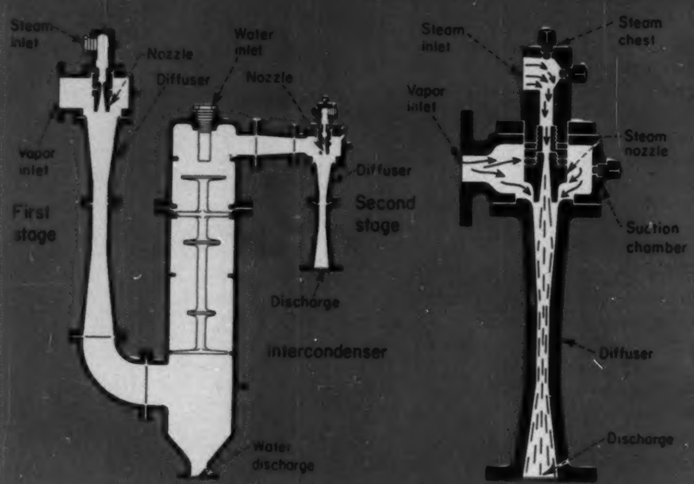
Although reciprocating compressors as large as 6,000 hp. are presently being manufactured, machines of this size are the exception rather than the rule. A 1,000 hp. reciprocating compressor is still a large compressor, in fact well above the average horsepower of all reciprocating compressors. A 1,000 hp. centrifugal compressor is considered a relatively small machine.

The solution of any problem first requires that the problem be stated in its entirety. The writer believes that the best solution to a compression problem can be obtained by presenting the complete problem to the compressor manufacturer. Then let him offer his best solution, be it reciprocator, centrifugal or a combination of the two.

In borderline cases, and there will be many, it is assured that companies which manufacture only centrifugal compressors and those which manufacture only reciprocating compressors will each submit their best proposition. Those manufacturers who build both types of machinery, and there are several, will submit alternate propositions setting forth therein advantages of both. By this approach, the purchaser stands to gain through the combined thinking of the compressor industry.

The writer appreciates contributions to this article from the following men in the Ingersoll-Rand Co.: Mr. T. W. Chapman, Turbo Blower Dept.; Mr. W. W. Paschke, Compressor Engineering Dept.; Mr. R. W. Kiebler, Compressor Engineering Dept.

Two-stage ejector on left has intercondenser; single stage, right shows flow. (Fig. 1)



Wide Application for Ejectors

Distillation—mineral oils, fatty acids, glycerine, molecular stills.
Deodorizing—edible oils.
Deaeration—clay products, vacuum packing, degassing metals.
Drying—shelf and rotary dryers, drying kettles, freeze drying.
Evaporation—single and multiple effect evaporators, recompression evaporators.
Refrigeration—chilled water by evaporation.
Power—vacuum for condensing turbines.
Miscellaneous—creosoting lumber.

Steam Jet Ejectors

Robert Frumerman

Most widely used among industrial jet pumps is the steam-jet ejector. It has low first cost, low maintenance cost, simple design, no moving parts and requires little space.

Ejectors are easy to operate. Difficulties encountered most commonly are wet steam or insufficient steam pressure, both simple to correct.

Because there are no moving parts, maintenance is insignificant and parts are replaced infrequently. New parts are easy to install.

Operating costs for ejectors, on an annual basis, are usually much greater than installed equipment cost because initial cost is low and steam consumption is high. Also, multi-stage ejectors operating with intercondensers require appreciable quantities of water.

Applications for ejectors exist in every vacuum process. Some are listed in the accompanying table.

Velocity-Pressure Change

Jet pumps are unique among compressors in two respects: the prime mover and compressor are one unit and the working fluid mixes with the fluid being compressed.

In Fig. 1 is a sectional view of a single ejector stage. Motive fluid, such as high-pressure steam or air, is expanded to low suction pressure through a convergent-divergent nozzle.

This essentially isentropic expansion converts much of the pressure head to velocity head. You can visualize the energy involved when you realize that the motive fluid in a high-vacuum ejector may leave the nozzle at ten times the velocity of sound.

Motive fluid and fluid entrained from the suction inlet mix at constant pressure in the suction chamber. During mixing, the jet stream gains weight but loses some velocity.

The stream then enters the venturi-shaped diffuser where most of the remaining velocity head is converted back to pressure. Pressure at the ejector discharge is lower than the motive-fluid inlet pressure, yet greater than the suction pressure.

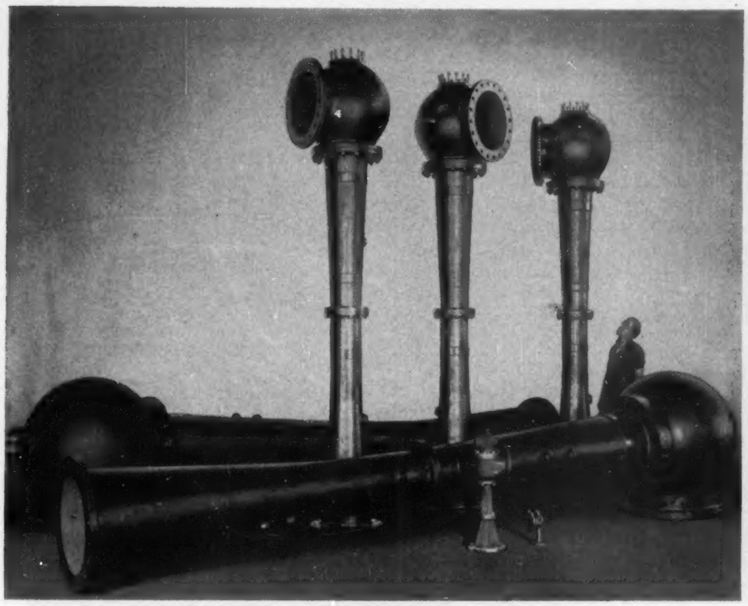
An ejector consists of one to six stages in series, each stage performing a part of the compression work. The compression ratio of any stage is limited to 10 for low vacuum-stages or 20 for high-vacuum stages. Practically speaking, a stage is usually operated lower than these upper limits to achieve economy of steam consumption.

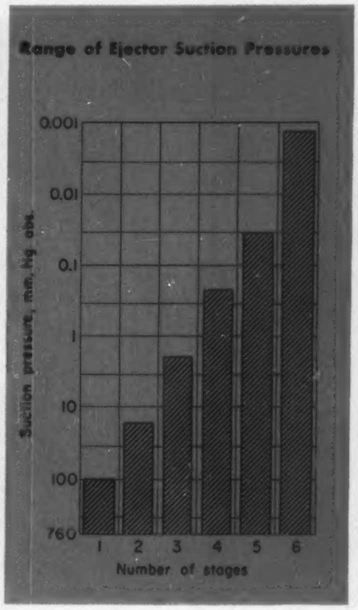
A bar chart of practical suction pressure range for any number of stages is shown on p. 197. This is intended only as an application guide, and does not represent the maximum attainable limits.

Operating Traits

An understanding of ejector performance characteristics is obtained through a knowledge of its component behavior. The diffuser follows the same theory as flow nozzles. It may be classified according to whether the fluid flowing makes the transition between subsonic and sonic velocity or whether all flow is subsonic.

According to flow theory, transition between sonic and subsonic





Trickle or torrent of gas or air is pumped by ejectors. (Fig. 2)

flow occurs at some minimum (critical) pressure ratio, in this case the ratio of the ejector's maximum stable discharge pressure to suction pressure.

Subcritical ejectors have compression ratios less than two. They are used only as single stages, have many operating variables which yield a performance map rather than a unique characteristic curve.

An ejector operating with a compression ratio above the critical pressure ratio is more constrained in its degree of operating freedom and has a typical characteristic curve as shown in Fig. 3. All the following discussion will be confined to this type.

When operating stably, each stage has a fixed suction pressure for a given weight flow of the same entrained fluid. This relationship is so well defined that ejectors are occasionally used to meter loads in field installations using the calibration curve for known loads.

Stability occurs when neither an increase in motive fluid pressure nor a decrease in back pressure will lower the suction pressure further under constant load (weight flow of entrained fluid). In other words, an ejector is stable when discharging to a pressure less than its maximum stable discharge pressure.

Most ejectors have two maximum stable discharge pressure curves. If an ejector is operating stably and its discharge is throttled, the back pressure will increase to some point where the suction pressure will suddenly rise and fluctuate. This is the "break" back-pressure.

Now, if the back-pressure is reduced slowly by opening the discharge throttle valve, another point will be reached where the suction pressure returns to its initial low value and pressure fluctuations cease. This point is called the "pick-up" back-pressure and is less than "break" back-pressure.

Ejectors should be designed to operate at less than pick-up back-pressure. Then a momentary break in operation due to wet steam or fluctuation in steam pressure will not prevent a return to stable operation.

When ejectors are operated in series as a multi-stage machine, the maximum stable discharge pressure of each stage must be greater than the corresponding suction pressure of the following stage.

From tests on a typical two-stage ejector, the suction pressure of each stage is plotted against load to the first stage, Fig. 4, Curves 1 and 2. When the suction pressure of the second stage, Curve 2 exceeds the maximum stable discharge pressure of the first stage, Curve 3, the first stage will be operating unstably, points A, A′. In other words, suction pressure of the second stage will exert back pressure on first stage discharge forcing it to reach break back-pressure.

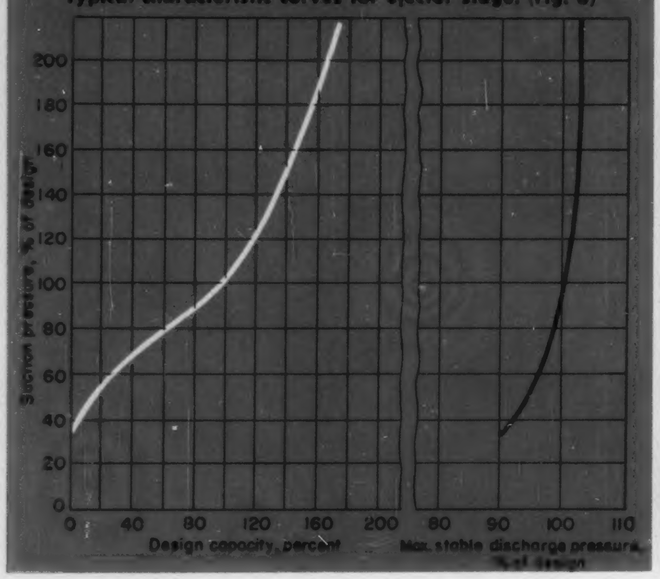
The "carry-out" of the unit refers to how far the first stage will operate along its stage characteristic, Curve 1, before the break occurs.

Carry-out of the first stage may be improved from Point *A* of Curve 1 to Point *B* by either of two methods. One is to increase the first stage maximum stable discharge pressure from Curve 3 to Curve 3a, by designing for higher steam consumption. Operationswise, discharge pressure can be improved somewhat by increasing the motive steam pressure (and flow). However, more than 5-10% increase in steam flow reduces capacity because the diffuser becomes choked.

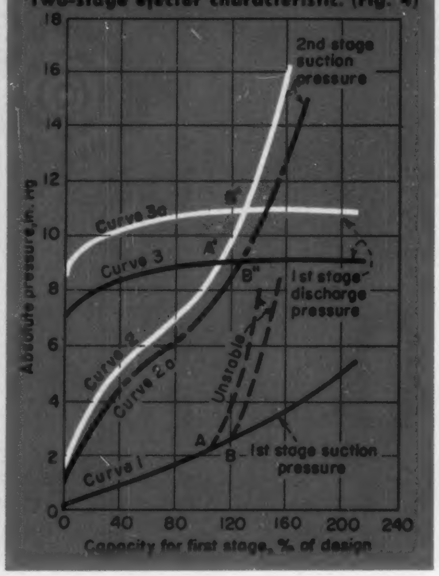
If there is no intercondenser between stages, the second stage must be designed and built to handle the increased flow of steam. Capacity of a stage cannot be altered appreciably by operating variables.

The second method for improving carry-out of the first stage is to merely increase capacity of the

Typical characteristic curves for ejector stage. (Fig. 3)



Two-stage ejector characteristic. (Fig. 4)



second stage from Curve 2 to 2a. With either the first or second method there will be a higher overall consumption of steam.

Curve 3 of Fig. 4 shows the first stage discharge pressure falling off rapidly at no load. If Curve 3 dipped below Curve 2 (1st stage discharge pressure is less than 2nd stage suction pressure), the ejector would be unstable at shut-off.

Sometimes, this is done deliberately in the interest of conserving steam. To insure stable shut-off, the remedy is the same as described for increasing carry-out, at an increased cost for motive steam.

Condensing or Non-Condensing?

To keep steam consumption at a minimum, either surface or direct-contact condensers often are used ahead of the first ejector stage, or between stages. This decreases the vapor load and, thereby, total weight flow to the stage following the condenser.

The surface-type condenser is desirable for heat economy, product recovery, low head room, or prevention of water pollution. Where these are unimportant, the direct contact condenser has the advantages of lower cost, more efficient cooling, capacity to handle more non-condensibles, and ability to use dirty water without fouling.

Direct-contact condensers mix cooling water directly with the vapors to be condensed. They are called barometric condensers where installed with a long drain pipe or barometric leg having sufficient elevation so that water can drain from vacuum to atmosphere.

If the condenser has a condensate pump instead of a barometric leg, it is called a low-level condenser. Condensate pumps are seldom used because it is too easy to flood the system if pump or power fails.

Use of condensers and selection of interstage pressures are matters for economic balance involving first cost of unit and cost of utilities, i.e., steam and water.

For a given capacity, a two-stage, non-condensing ejector will have a large second stage that uses more steam than if an intercondenser were used. However, the non-condensing ejector needs no water, condenser, cooling tower capacity, or hot well. Generally, it may be installed less expensively and more accessibly since it need not be elevated for a barometric leg.

How Big?

Size and steam consumption of an ejector are determined primarily by the amount of the load, the absolute suction pressure at which this load is handled, steam pressure and whether condensers are used ahead of any of the stages. If condensers are used, other important considerations are the fraction of the load which is condensible and the entering cooling water temperature.

With enough care a system can be made leak-tight. However, it is wise to compromise, when selecting a vacuum pump, by choosing a pump that will handle a reasonable amount of leakage. After all, a $\frac{1}{8}$-in.-dia. hole will pass about 14 lb. per hr. of air into a system operating at less than half an atmosphere.

Fig. 5 shows leakage values which the Heat Exchange Institute assigns to commercially tight systems. On H.E.I. recommendation, these values should be doubled to specify the ejector load. Leakage figures from the chart must be increased if an agitator is in the process.

Presence of liquid in the system means that vapors from the liquid will be carried to the vacuum pump by the non-condensible gas, in sufficient quantity to saturate the gases. In the case of a pure liquid, the partial pressure due to the vapor equals its vapor pressure at the

temperature of the system. Then the following equations apply:

$$P_{nc} = \pi - P_v \quad (1)$$

$$P_{nc}/N_{nc} = P_v/N_v \quad (2)$$

where π = total pressure, P = partial pressure, N = number of moles per hr. and subscripts nc and v refer to non-condensible and vapor.

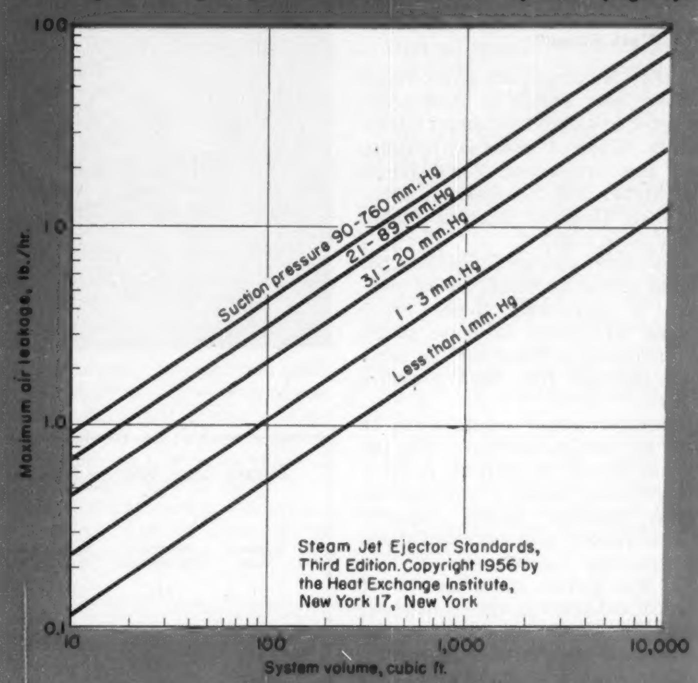
Reduce to Common Basis

Having determined the actual weight flow to be pumped by the ejector, it is necessary to reduce this load to a common basis to determine steam consumption. The basis generally used is the equivalent weight flow of 70 F. dry air which will behave exactly like the actual load in the ejector and will require the same amount of motive steam.

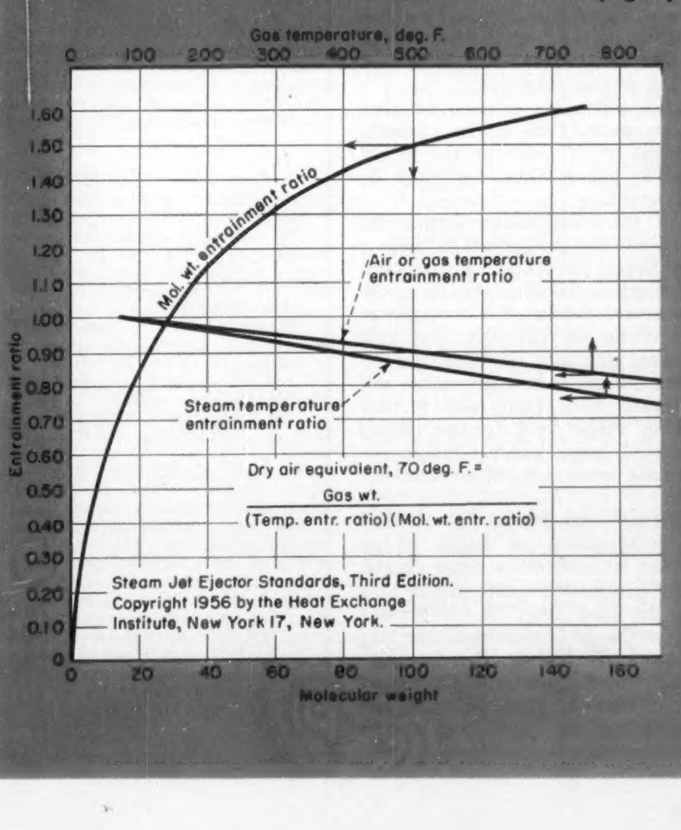
The amount of fluid handled by a pound of motive steam operating between constant pressure limits increases with the molecular weight and decreases with the temperature of the fluid. These relationships are shown in Fig. 6.

Five cases apply to the determination of equivalent air load. These

Leakage into tight systems affects load on ejector. (Fig. 5)



Equivalent air load needed to determine steam use. (Fig. 6)



How to Find Equivalent Air Load

Air—For air over 70 F. divide actual weight flow by air temperature-entrainment ratio.

Steam—Divide actual weight flow by steam temperature-entrainment ratio and molecular weight-entrainment ratio.

Air-Steam Mixtures—Divide weight of air by air temperature-entrainment ratio. Divide weight of steam by steam temperature-entrainment ratio and molecular weight-entrainment ratio. Add the results together.

Gas Mixture, No Steam—Find the average molecular weight of the gas. Divide the actual total weight flow by the air temperature-entrainment ratio and molecular weight-entrainment ratio.

Gas Mixtures With Steam—Calculate air equivalent of gas as in mixture of gases without steam. Calculate air equivalent of steam as noted above. Add the two 70 F. air equivalents together.

are shown in the table next to the graph.

How Much Steam?

Other factors which affect steam consumption should be understood in order to select a jet pump intelligently. Some of these are obvious, once they are stated. For example, the higher the compression ratio, the more steam is required to handle a given load.

Also, more energy is available per pound of motive steam as its pressure is increased. Hence fewer pounds of higher pressure steam are required to compress the same load through the same pressure limits.

However, while this fact can be used for design purposes, once the ejector is built an increase in operating steam pressure will not increase capacity. Rather, capacity will decrease due to increased steam flow choking the diffuser.

A less logical characteristic of ejector behavior is that superheat in the motive steam does not appear to increase the available energy.

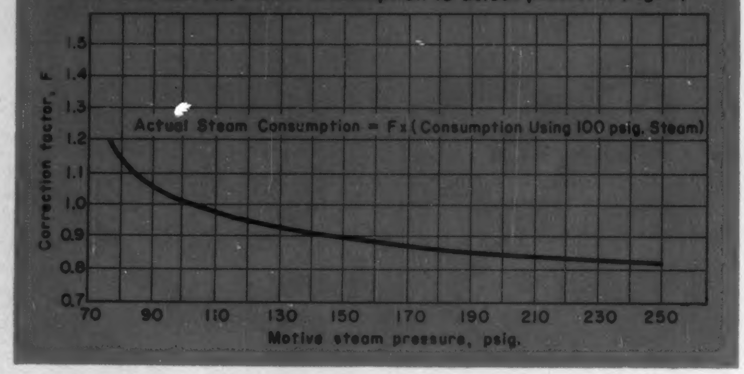
Condensation ahead of an ejector stage reduces the weight of vapor to be compressed by that stage. In a two-stage non-condensing ejector, all the load and all the first stage motive steam must be compressed in the second stage.

If a condenser is used between stages, most of the motive steam is condensed. If some of the initial load is vapor, this, too, may be condensed.

All these situations reduce the work of the second stage ejector and hence its steam consumption. Since gases leaving the intercondenser are saturated with vapor at intercondenser pressure and exit temperature, any increase in pressure or decrease in temperature will condense more vapor and further reduce vapor load to the second stage. A lower water temperature means a lower saturation temperature.

Water temperature is increasingly important in design of an ejector with three or more stages. This temperature determines how far the load must be compressed before the first intercondenser may be used. Obviously, the intercondenser must operate at a pressure higher than the vapor pressure corresponding to inlet condensing water temperature.

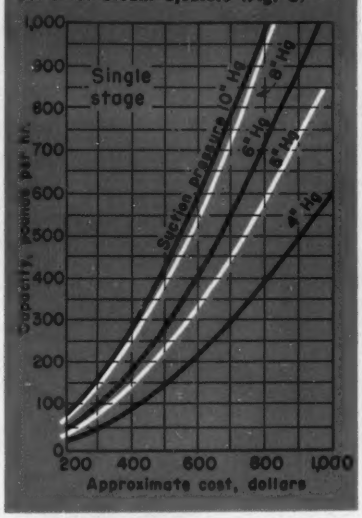
Factor corrects steam consumption to actual pressure. (Fig. 7)

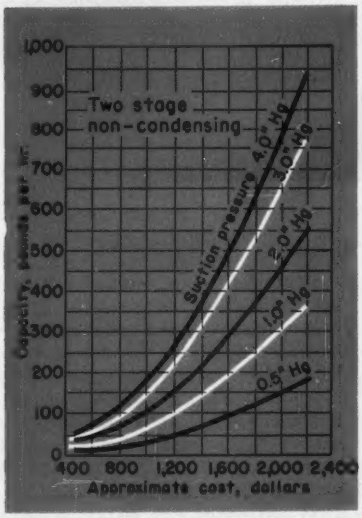


Steam and Water Required for Various Ejectors—Table I

Number of Stages	Barometric Intercondenser	Suction Press., In. of Hg Abs.	100 psig. Motive Steam, Lb. per Lb. 70 F. Air Equivalent	70 F. Cooling Water, Gpm. per Lb. of 70 F. Air Equivalent	Air, % in Air-Water Vapor Mixture
1	No	4.0	6.90	None	0–100
		5.0	4.90		
		6.0	3.70		
		7.0	3.00		
		8.0	2.60		
		9.0	2.30		
		10.0	2.05		
2	No	0.5	34.5	None	0-100
		1.0	16.5		
		2.0	9.30		
		3.0	6.75		
		4.0	5.30		
		5.0	4.60		
2	Yes	0.5	10.0	0.400	100
		1.0	6.30	0.250	
		2.0	4.45	0.150	
		3.0	3.50	0.115	
		4.0	3.00	0.095	
2	Yes	0.5	8.70	0.345	75
		1.0	5.45	0.245	
		2.0	3.80	0.160	
		3.0	3.00	0.130	
		4.0	2.55	0.115	
2	Yes	0.5	7.05	0.310	50
		1.0	4.45	0.225	
		2.0	3.05	0.170	
		3.0	2.40	0.140	
		4.0	2.05	0.125	
2	Yes	0.5	5.20	0.330	25
		1.0	3.20	0.220	
		2.0	2.10	0.155	
		3.0	1.65	0.135	
		4.0	1.45	0.125	

Costs for Steam Ejectors (Fig. 8)





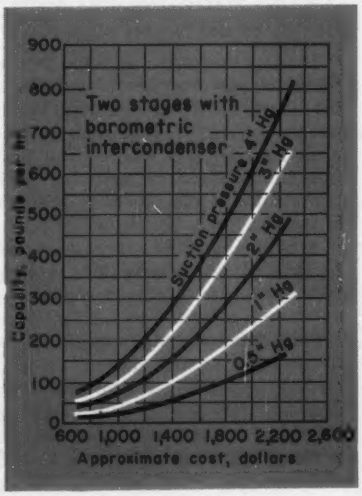


Table 1 gives steam consumption for single and two-stage ejectors and water consumption for condensing type. Since these figures are based on 100 psig. motive steam, Fig. 7 must be used to correct for steam pressure. Fig. 7 applies better to single-stage ejectors but may be used to obtain approximate correction when figuring for two-stage machines.

These data only pertain to ejectors where each stage uses at least 180 lb. per hr. of motive steam. If less steam is used, losses represent a higher fraction of available energy so that steam consumption must be increased accordingly.

Fig. 8 shows cost data and needs no explanation. How steam consumption and cost compare for a given load through condensing and non-condensing ejectors is shown in the accompanying box, below.

Size of a single-stage ejector can be approximated by limiting the suction velocity to 200 ft./sec. and computing the nearest nominal pipe size. The discharge opening will usually be the same as the suction opening.

Over-all length of the ejector is about 10-11 times the nominal pipe size at the suction opening. For example, an ejector with 6-in. inlet flange will have an over-all length of 60-66 in.

Ejectors are available in a variety of materials for every service. Commonest are stainless-steel nozzle and cast-iron suction chamber and diffuser. Other cast metals such as bronze or Ni-Resist are used frequently. Large-size diffusers and air chambers may also be steel plate. Special materials for corrosive service include graphite and Haveg.

Acknowledgment is gratefully made to George Stout, Application Engineer, Elliott Co., Jeannette, Pa., for preparing cost and steam consumption data exclusively for this report.

Compare Condensing Vs. Non-Condensing

What's Needed

Load to be handled is 100 lb. per hr. of air saturated with water vapor at 1 in. Hg abs. and 70 F. Compare steam consumption and cost for two-stage condensing and non-condensing ejectors using 200 psig. motive steam and water at 70 F.

How to Solve

Since load to the ejector is air-water vapor mixture exact proportions of each are calculated. Then the equivalent load of dry air is determined. Using this, steam consumption is computed and costs compared for condensing and non-condensing units.

The amount of water vapor in the load is calculated with the help of Eq. (1) and (2). Vapor pressure of water at 70 F. is 0.739 in. Hg abs.

$P_{air} = 1 - 0.739 = 0.261$ in. Hg abs.

$N_{air} = 100/29 = 3.45$ moles/hr.

N_{water} 0.739 (3.45/0.261) = 9.76 moles/hr.

9.76 x 18 = 175.4 lb./hr. water vapor in load

Next, the actual load must be determined as the equivalent weight flow of dry air at 70 F. before steam consumption can be calculated. Referring to Fig. 6 the temperature entrainment ratio for 70 F. steam equals 1. Using the other curve on the same chart, the molecular weight entrainment ratio for steam is found to be 0.81.

Now, the 70 F. air equivalent of steam is 175.4/(1 x 0.81) = 216.5 lb./hr. The 70 F. air equivalent of air is 100 lb./hr. So, the total load in terms of 70 F. air equivalent is 316.5 lb./hr.

Non-condensables in the load are 100 (100/275.4) = 36.3%.

Refer now to Table I to find that 16.5 lb. of 100 psig. motive steam are needed per lb. of 70 F. air equivalent. A correction factor of 0.85 (Fig. 7) must be applied to this to obtain consumption of 200 psig. steam. Thus, total consumption of steam is 316.5 x 16.5 x 0.85 = 4,450 lb./hr.

To obtain steam consumption for condensing ejector refer again to Table I and interpolate between 3.20 lb. of steam per lb. air and 4.45 for air-water vapor mixture containing 36.3% non-condensables. Answer is 3.77 lb. of steam/lb. of air.

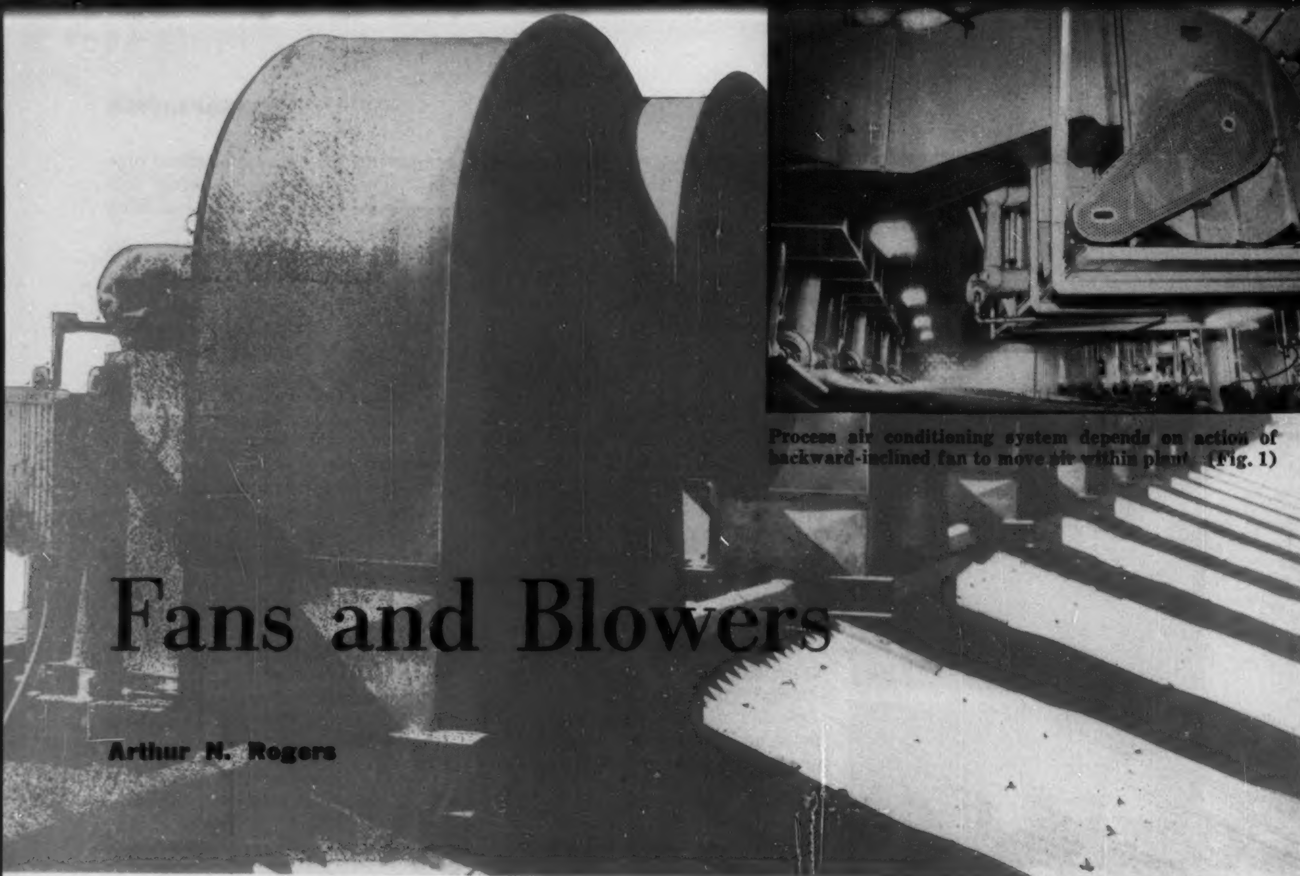
Then total steam consumption for the condensing unit is 316.5 x 3.77 x 0.85 = 1013 lb./hr.

Again from Table I water consumption is 0.222 x 316.5 = 70.2 gpm.

If the air equivalent load were present as dry air, steam consumption of the non-condensing ejector would not change. But for the condensing unit it would be 316.5 x 6.30 x 0.85 = 1693 lb./hr. steam. Water consumption is 316.5 x 0.250 = 79.2 gpm.

Comparative data are tabulated below. Cost data are from Fig. 8.

Inter-condenser	% Air in Load	Steam, Lb./Hr.	Water, Gpm.	First Cost, Dollars
No	36.3	4,450	0	1,910
Yes	100	1,693	79	2,220
Yes	36.3	1,013	70	2,220



Process air conditioning system depends on action of backward-inclined fan to move air within plant. (Fig. 1)

Fans and Blowers

Arthur N. Rogers

Today, fans handle greater volumes of compressible fluids than any other type of machine. Primarily, fans handle air. No industry can exist today without controlled handling of air, and the chemical and process industries are no exception.

The distinction between fans and compressors is somewhat fuzzy. Generally speaking, fans operate at pressures low enough so that compressibility of the fluid can be neglected. Thus, inlet and outlet volumes are considered alike.

The maximum pressure at which this assumption can be made safely is about one pound per square inch. Although some "fans" are designed for pressures higher than 1 psig., the great majority are limited to lower pressures.

Fans, then, are designed to move comparatively large volumes of gas at low pressures. In fan work, pressure is measured normally in inches of water.

Fan Types

Basically, fans are classified by direction of air flow. Fans having radial flow are called centrifugal fans, because centrifugal force builds up velocity and pressure in the gas. Air enters the centrifugal fan parallel to the fan shaft, turns 90 deg., passes between the blades of the fan wheel and discharges in a plane perpendicular to the shaft. Flow of the fluid is similar to that in a centrifugal pump.

Fans that create continuous flow, parallel to the fan shaft, are called axial-flow fans. These fans produce flow by the screw or propeller action of the fan wheel or impeller. Simple axial-flow fans are either tube-axial or propeller fans.

Propeller fans are designed to operate against little or no resistance pressure. They blow or exhaust from one space to another or to the atmosphere.

Tube-axial fans are designed to develop higher pressures. Guide vanes added to a tube-axial fan, either ahead of or following the impeller, make it a vane-axial fan. These vanes straighten the helical flow pattern to convert velocity into useful pressure, thus increasing the efficiency.

Fans may be classified further by application, such as: ventilating, industrial, forced draft, induced draft, etc. There is considerable overlap in actual use, however. For example, an industrial fan might be used to supply forced draft for a boiler; or an induced draft type used to exhaust from a cement kiln.

Testing and Rating

Testing method for fans is set forth in the Standard Test Code for Centrifugal and Axial Fans, which is jointly sponsored by the American Society of Heating and Air Conditioning Engineers and the National Association of Fan Manufacturers, Inc.

A typical test set-up consists of an open-inlet fan with a transformation piece and a straight, circular duct attached to outlet.

Straightening vanes, in the form of an egg crate, are set in the duct to smooth out the air flow. Beyond the straightener, a pitot tube is inserted into the duct to measure pressure (velocity and static).

At the end of the duct is a volume-flow controller. This may consist of a series of interchangeable plates with orifices of various sizes, or a flat plate or similar device that is swiveled like a damper to vary the opening between the end of the duct and the plate.

Fan is powered with a dynamometer or calibrated electric motor so that power input to the fan can be measured. Readings are taken for various outlet openings to obtain the fan performance from blocked tight (no volume flow) to wide open (maximum volume flow).

Fundamental fan performance for a given size at constant speed and gas density is expressed by curves of pressure (total and static), horsepower input and efficiency (total and static) plotted against volume flow as the abscissa. From these basic data performance can be calculated for any size fan, geometrically similar to the test fan, at any speed and any density.

The quantities used to determine fan performance are defined by the test code as shown in the accompanying box, p. 204.

Two types of efficiency are encountered in relation to fans: mechanical or total efficiency and static efficiency. Mechanical efficiency relates horsepower input to air horsepower on a total pressure basis, whereas static efficiency is based on static pressure.

To calculate the performance of other geometrically similar fans from basic test curves, use is made of the fundamental fan laws. Simply stated, the three fan laws are as follows:

$$V_1/V_2 = (D_1/D_2)^3(n_1/n_2) \quad (1)$$

$$p_1/p_2 = (D_1/D_2)^2(n_1/n_2)^2(\rho_1/\rho_2) \quad (2)$$

$$P_1/P_2 = (D_1/D_2)^5(n_1/n_2)^3(\rho_1/\rho_2) \quad (3)$$

Where V = volume, cu. ft.; D = diameter, ft.; n = rotational speed, rpm.; p = pressure, lb./sq. ft.; ρ = density, lb./cu. ft.; P = ft.-lb./sec.

Effective use of the fan laws is by no means confined to fan engineers. They may be put to good use on existing air handling systems.

For example, suppose it should become necessary to increase the volume of gas handled by speeding up the fan. Volume will increase directly with the increase in speed. Required horsepower will increase as the speed ratio cubed. This is according to fan laws (1) and (3).

Selection of fans from performance curves would be a rather difficult and time consuming procedure, at best. Fan manufacturers, therefore, publish the performance data in tabular form available to users.

These performance tables generally are a list of volumes in even increments of outlet velocity with speed and horsepower tabulated for various static pressures. These data are shown for each fan size and are based on air at standard conditions. In most cases the user need make no calculations except simple interpolation between values in the tables to reach the answer.

Characteristics

Although exact fan performance can be determined only through testing or through reference to published data in the case of established designs, the over-all characteristics can be predicted in advance.

The characteristics of centrifugal fans are determined by the type of blading. There are three basic blading types: radial, forward curved and backward inclined.

Modifications and combinations of these types exist but in general the characteristics are determined by the shape at the blade tip. For example, a fan wheel with blades curved forward at the base and radial at the tip will behave like a radial-bladed fan.

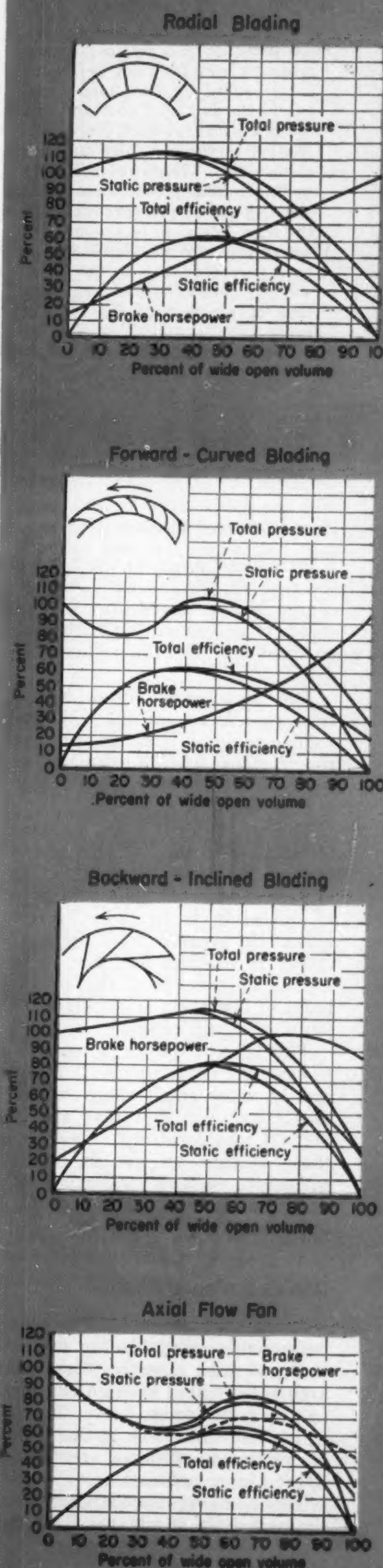
Radial Blading

Radial bladed or "paddle wheel" fans were the earliest design. These fans have characteristics which place them midway in the centrifugal group, Fig. 2.

Speed for a given pressure is moderate; size for a given volume is medium. The horsepower curve rises with a medium slope and is almost a straight line. Efficiency is medium to low. Stability of the pressure curve is excellent. This wheel type has good resistance to abrasion.

Because centrifugal force tends to keep the blades clean, this type of blading is used for conveying, induced draft and other such applications where suspended solids must pass through the fan.

Fan Operating Curves. (Fig. 2)



Speaking the Fan Language[1]

Total pressure of a fan is the rise of pressure from fan inlet to fan outlet as measured by two impact tubes, one in the fan inlet duct and one in the fan discharge duct, corrected for friction to the fan inlet and outlet, respectively. Where no inlet duct is used, the total pressure on the inlet side is 0 and no pressure readings on the inlet side shall be taken.

Velocity pressure of a fan is the pressure corresponding to the average velocity determination from the volume of air flow at the fan outlet area.

Static pressure of the fan is the total pressure, less the fan velocity pressure.

Standard air density is 0.075 lb. per cu. ft.

Unit of pressure is 1 in. of water column, density of 62.3 lb. per cu. ft.

Volume handled by a fan is the number of cubic feet of air per minute expressed at fan outlet conditions.

Power output of a fan is expressed in horsepower and is based on fan volume and fan total pressure.

Power input to a fan is expressed in horsepower and is the measured horsepower delivered to the fan shaft.

Mechanical efficiency is the ratio of power output to power input.

Static efficiency is the mechanical efficiency multiplied by the ratio of static pressure to total pressure.

Air horsepower is (volume) (pressure)/(6356) or (0.0001575) (volume) (pressure) at standard air density of 0.075 lb. per cu. ft.

Efficiency equals (air horsepower)/(horsepower input)

[1] *As defined in Standard Test Code sponsored by American Society of Heating and Air Conditioning Engineers and National Association of Fan Manufacturers, Inc.*

Forward-Curved Blading

Introduced prior to the turn of the century, the fan with forward-curved blading is essentially a low-speed, large-volume fan with small physical size for the volume produced.

The horsepower curve, Fig. 2, rises rapidly toward the wide-open volume region. Unless the pressure requirements can be estimated accurately the use of oversize motors is necessary.

The pressure curve has a characteristic dip in the low volume portion of the curve. Stability of operation is uncertain unless the point of operation is on the wide-open side of the pressure peak. Peak efficiency is medium but, due to the nature of the curve, the selected point of operation is usually in the lower efficiency range.

This type of blading is restricted to clean-air applications. It is used mostly when small space requirements and low first cost are important considerations. Because of these factors its use in unitary equipment such as ventilating sets, unit heaters and air conditioning units is widespread.

Backward-Inclined Blading

Of the three basic blading types, backward-inclined blading was introduced most recently. These fans are characterized by high efficiency and a horsepower curve, Fig. 2, which rises to a peak in the region of maximum efficiency, then falls off at higher volumes.

This non-overloading horsepower characteristic eliminates need for oversized motors. In combination with the stable pressure curve, it has made this fan type the most widely used for clean-air commercial and industrial applications. Rotative speeds are comparatively high, thus facilitating direct or V-belt drive to standard a.c. motors.

Airfoil blading, presently being introduced on a commercial scale, is a modification of backward-inclined blading that retains its desirable characteristics, combined with higher efficiency and quieter operation.

Axial Flow Fan

There are so many types of axial-flow fans from the vane axial to the propeller fan that it is impractical to try to show anything more than a representative sample. Blading types vary from a sheet metal disk that is split and twisted, to highly efficient tapered airfoil blades. Performance varies accordingly.

In general, axial-flow fans have high rotative speeds and medium efficiency. Characteristically, the efficiency peak, Fig. 2, is in the high volume range. In most cases, maximum horsepower is reached in the blocked-tight position rather than wide open.

Axial-flow fans are generally more noisy than centrifugal fans and consequently find their widest application in the industrial field where quiet operation is not of paramount importance. Although axial-flow fans have been designed for high pressures, by far the majority are designed for low-pressure applications in the 0-3 in. static-pressure range.

Fan Selection

System Characteristics—Fan performance curves are made at a constant fan speed with the orifice controlled from blocked tight to wide open. Variation of the orifice thus simulates a varying system resistance.

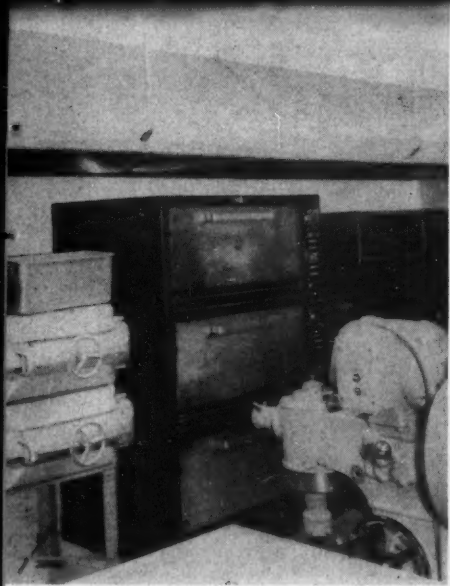
If the orifice is held constant and fan speed changed, pressure and volume can be plotted to produce what is known as the system curve.

From fan laws (1) and (2) it is known that the volume varies directly as the speed and the pressure varies as the square of the speed at constant diameter. A system curve is, therefore, a parabola with the pressure changing as the square of the volume.

This is true for any normal unchanging system. If a single pressure and volume point on the system is known, it is possible to draw the system curve. When a system curve is superimposed on a fan curve the crossing point of the system curve and the pressure curve is the point of operation of the fan on the given system.

System resistance is calculated by totaling the resistance of the various system components. Resistances of coils, filters, grills and other components are given in the manufacturers' literature.

Effect of Density—Change in density due to the effects of temperature and altitude also follows the fan laws exactly. Fans, like pumps, are inherently constant-volume machines. This means that



Hood over processing area exhausts fumes and vapors. Either centrifugal or axial fans can be used. (Fig. 3)

with a given speed and other factors constant, volume of fluid flowing will be the same regardless of the density.

Total head against which the fan operates will vary directly with the density of the fluid as will the head which the fan develops. Power is the product of the volume and the head, and therefore, the power required will also vary directly as density.

It is standard practice in the fan industry to publish performance tables, performance curves, duct resistance tables, etc., for standard dry air at +70 F. at sea level (pressure 29.92 in. Hg) having a density of 0.075 lb./cu. ft. When fans are selected to handle gases at other than standard conditions, density correction factors must be used.

Density of air is inversely proportional to the absolute temperature and directly proportional to the absolute pressure. For example, the ratio to standard conditions for air at 1,000 ft. altitude (28.86 in. Hg) and at 200 F. would be $(460 + 70)(28.86)/(460 + 200)(29.92) = 0.774$.

To select a fan for high temperature or altitude conditions, the system resistance is figured in the usual manner and the fan pressure requirement determined for standard conditions. This is otherwise known as the "cold" pressure.

From the fan performance table, select a rotational speed for the volume desired, at the "cold" static pressure. The fan will produce the same volume at this speed, regardless of the density of the air being handled. But the pressure actually developed at the new temperature or altitude conditions is the "cold" static pressure multiplied by the density ratio.

The brake horsepower required is the bhp. under the "cold" static pressure conditions multiplied by the density ratio.

In some instances a constant weight of gas is required despite a density change. In this case dividing the fan inlet volume at standard conditions by the density ratio will give the volume desired at the operating conditions. Calculate the "cold" static pressure for the fan inlet volume and proceed as above.

Fan Evaluation—Fan performance tables indicate that for the same working conditions, there is a choice of several fans. For similar working conditions, the larger the fan the lower the horsepower and speed (up to the point of maximum efficiency). Therefore, it is necessary to balance the extra cost of operation of the small fan against the additional cost and space consumption of the large size.

Fans operating at high efficiency will also operate at their minimum-noise level which in some cases can be evaluated along with the power cost.

Drive Selection—Fans for most applications are V-belt driven and reasonable care and judgment should be used in the drive selection. Most V-belt drive manufacturers include a service factor in their selection tables which is adequate for fan duty. When there is any doubt it is better to select a drive for a slightly higher horsepower rating.

It is always desirable to select the drive on the basis of motor horsepower rather than fan horsepower because the starting torque of the motor is the governing factor. Whenever possible select an adjustable drive so that the fan speed may be adjusted after installation to take care of possible volume variations.

Avoid too large a differential between fan speed and motor speed. In many instances, the difference in price between an 1,150 rpm. and a 1,750 rpm. motor can more than offset the difference in drive price.

Motor Selection — Standard torque motors are entirely satisfactory for fan duty in general. In a few cases fans are selected for very low outlet velocities and pressure and the fan horsepower is very low for the size of fan. For these applications select a motor with high starting torque or an oversize motor to insure proper starting.

Methods of Fan Control

There are three basic methods for controlling the output of a fan. The first method is to vary the fan speed by the use of slip-ring motors, fluid or magnetic couplings, and to a certain extent by adjustable pitch drives. The second method is to use inlet or outlet dampers which vary the system resistance. The third is to control inlet vanes to regulate the amount of work which the fan can do on the air.

In the average application the first method is not generally used because of the high first cost of slip-ring motors and fluid or magnetic couplings. Vari-pitch drives are satisfactory for minor initial control to balance or adjust the system. But they do not lend themselves to either automatic control while in operation or manual control over any considerable range.

Both outlet dampers and inlet-vane control lend themselves to either manual or automatic operation for controlling the output over a wide range at a low initial cost. Outlet dampers lower the volume output by increasing the system resistance. Thus fan operation changes along its characteristic curve as the pressure increases. At lower volumes the fan is working against a higher pressure and, therefore, pressure and power is wasted.

Vane control imparts a spin to the air at the inlet and, thereby, limits the amount of work the fan can do on the air. There is no increase in pressure and no wasted power.

Vane control is somewhat more expensive than outlet dampers. But in many cases, especially on larger size fans, the difference can be evaluated quickly in power savings. At 75% of normal volume the power consumed with outlet dampers is about 90% of normal, and with vane control about 75% of normal or a saving of about 15%. When a fan is to be run at 60-80% volume a large part of the time, vane control is particularly useful.

Centrifugal Compressors

E. S. Leonard

Use of centrifugal compressors is becoming more prevalent in industry today because plant capacities are increasing while process heat balances can often be improved with steam or gas turbine drivers. At the same time, installation costs for centrifugals are low and operating costs are reduced. Such units are being used in many applications. Typical of some of these are: air for blast furnaces, bessemer converters and wind tunnels. Among process industries they are used in chemical processes such as nitric acid and synthetic ammonia, and in refrigeration cycles handling ammonia, Freon-11 and hydrocarbon gases. Refineries have found many uses for centrifugal compressors in vapor recovery, catalytic reforming, catalytic crackers, ethylene plants and butadiene plants. Each of these applications calls for a variety of design considerations.

A few applications, along with typical compressor costs, are shown in the tabulation. Fig. 1 indicates the approximate pressure-volume range now covered by centrifugal compressors.

The basic function of a centrifugal compressor is to raise the pressure of the gas flowing through it. This is accomplished by accelerating the gas as it flows radially outward between the vanes of a rotating impeller, then converting its velocity energy to pressure in some form of diffuser. Types of centrifugal compressors may generally be identified by arrangement of staging, impeller design, and case construction.

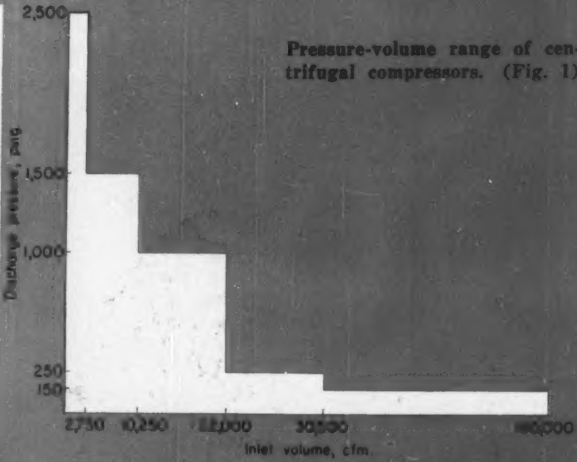
The compressor consists primarily of a stationary casing and a rotor. Compressor cases may be divided into two classes according to the design pressure of the machine—a horizontally split case for lower pressures, and a vertically split case for higher. The first (Fig. 2) has a casing joint in the horizontal plane at approximately the shaft centerline. The second (Fig. 3) has a casing joint in the vertical plane at right angles to the centerline of the shaft. Casings are usually designed to withstand internal hydrostatic test pressures of $1\frac{1}{2}$ times the maximum working pressure.

Compressor rotor design differs with various manufacturers as well as with condition requirements. The impellers may be either single- or double-flow, as well as of open, closed or mixed-flow type. The kinetic energy of the gas leaving the rotating element is converted into pressure in any one of various ways. Depending upon the requirements they include an open diffuser, a bladed diffuser or a volute.

Two methods of rotor support are generally used. In the beam type construction, the impellers

Some Typical Applications of Centrifugal Compressors

Application	Pressure, Psig.	Plant Capacity	Compressor Cap., Bhp.	Cost, $/Bhp.
Utility—Soot blowing	0–350	450,000 kw.	9,000	30
Refining—Cat. reforming	0–400	10,000 bpd.	2,500	30–50
Cat. cracking	0–35	50,000 bpd.	2,500	17
Chemical—Butadiene	0–150	40,000 tpy.	28,000	Air, 20 Gas, 50
Ethylene	0–500	40,000 tpy.	15,000	25
Nitric acid	0–120	40,000 tpy.	3,000	30



Pressure-volume range of centrifugal compressors. (Fig. 1)

are located between the bearings, in the cantilever type or overhung construction, the bearings are adjacent to each other with the impellers located at one end or at both ends of the shaft. Fig. 4 shows the construction of a typical four-stage compressor of the first type.

Centrifugal compressors are simple in construction. The essentials consist of the casing, impeller, diffuser (or volute), shaft and bearings, and shaft seal.

Principles of Operation

In a centrifugal compressor, the process occurring is a continuous flow of a compressible fluid so the fundamental concepts of fluid flow apply. The transfer of energy between rotor and fluid may be expressed in terms of gas velocities and direction of flow into and out of the rotor. The compressible fluid enters the impeller at its center, or eye, passes through the impeller changing in velocity and direction, and exits at the rim or impeller blade tip into the diffuser or volute. By application of Euler's equation, the energy imparted to the fluid by the rotor, as its head H, is:

$$H = \frac{1}{2g}\left[\left(U_2^2 - U_1^2\right) + \left(V_2^2 - V_1^2\right) + \left(v_2^2 - v_1^2\right)\right] \quad (1)$$

where U, V and v are velocities as defined by Fig. 5. The representation of energy transfer assumes a steady state of flow, and constant angular velocities and losses occurring outside the impeller. Under actual conditions, other factors must be considered to account for non-ideal conditions.

All losses that occur in a centrifugal compressor may be considered either hydraulic, thermal or frictional. The hydraulic losses include such items as disk friction, diffuser, impeller entrance and exit losses, turbulence and leakage. Energy losses transferred to the coolant and case radiation are considered thermal losses. Bearing and seal losses constitute friction losses.

For all practical purposes the work added to a compressible fluid in passing through an uncooled compressor is equal to the change in total enthalpy, or

$$W = \Delta h \text{ (where } \Delta h = c_p\,\Delta T) \quad (2)$$

In a cooled compressor there is another term Q in the equation (the net energy in transition) which can be neglected in an uncooled compressor:

$$W = \Delta h + Q \quad (3)$$

The work input W_{in} is defined as the work done by the impellers on the fluid being compressed. Part of the work is lost in fluid friction. The remainder, after conversion of the kinetic energy to pressure in the diffuser, can be considered as equivalent to the change in flow work PV, so

$$W_{in} - Q_f = \int_1^2 V\,dP \quad (4)$$

where Q_f is the loss due to fluid friction. With a perfect gas $PV = RT$, and PV^n = constant. When a perfect gas is compressed, the path the compression follows on the PV plane depends on the condition of the compression, which in turn determines the exponent in the equation, PV^n = constant. If the compression is isentropic (adiabatic), that is, having no transfer of heat to or from the surroundings, then the exponent is $k = c_p/c_v$, and the path is the adiabatic line on Fig. 6. This path is frictionless and theoretical, and cannot be followed by any actual compressor.

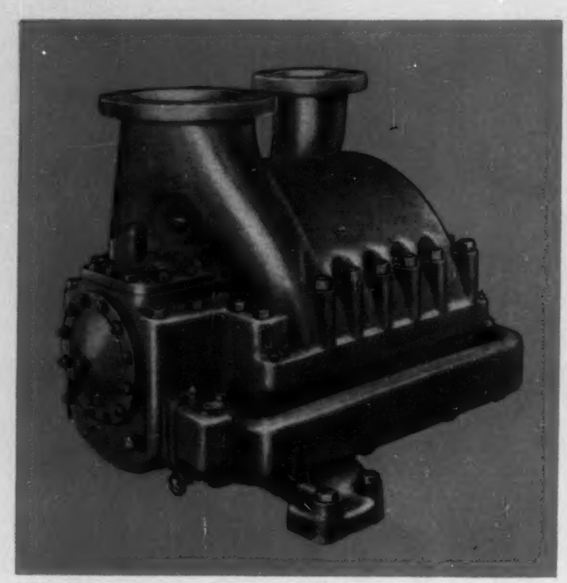
Instead, if the compressor is fully cooled, so that there is no change in gas temperature (again theoretical), then the exponent is unity and the isothermal path on Fig. 6 will be followed.

In an actual compressor involving friction, the compression will be neither adiabatic nor isothermal, but polytropic, with an exponent which will be greater than unity in a cooled compressor, and greater than k in an uncooled compressor. The compression will follow some path on Fig. 6 such as the curve labeled polytropic.

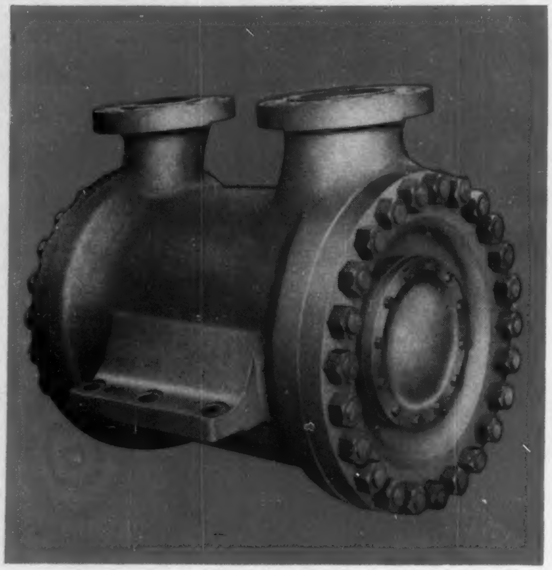
Hydraulic Efficiency

We can evaluate the work going into the process, W_{in}, as well as the flow work $\int V\,dP$. Their ratio $(W_{in} - Q_f)/W_{in}$ then gives the polytropic, or hydraulic, efficiency of the process:

$$\int_1^2 V\,dP = \frac{RT_1}{(n-1)/n} \times \left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right] \quad (5)$$



Centrifugal compressor with horizontal-split case. (Fig. 2)



Centrifugal compressor with vertical-split case. (Fig. 3)

$$W_{in} = \frac{RT_1}{(k-1)/k} \times \left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right] \qquad (6)$$

Whence

$$\frac{W_{in} - Q_f}{W_{in}} = \frac{(k-1)/k}{(n-1)/n} = \eta_h \qquad (7)$$

The hydraulic efficiency is only one of several ways in which compressor efficiency is expressed, but it is generally the most useful method, since it most closely represents the actual performance. It is a measure of the hydraulic perfection of the machine and remains the same for any gas, for cooled and uncooled compressors, and within limits, for any speed. Sometimes the adiabatic efficiency, or the isothermal efficiency may be used. Figs. 7 and 8 permit conversion of these efficiencies to hydraulic or polytropic efficiency.

Hydraulic efficiency is independent of the pressure conditions, but both adiabatic and isothermal efficiency contain the compression ratio, $r=P_2/P_1$. Therefore, in converting them to hydraulic efficiency, it is necessary to know the value of r.

Knowing the desired compression ratio r, together with the hydraulic efficiency and the properties of the gas to be compressed, we can calculate the head H produced by the compressor from a variation of Eq. (5):

$$H = \frac{ZRT_1}{(n-1)/n}\left(r^{(n-1)/n} - 1\right) \qquad (8)$$

Here Z is the compressibility factor* which corrects the ideal gas laws for actual gases. The polytropic exponent n can be determined from Eq. (7). And from the head and polytropic efficiency we can calculate the compressor power requirement, as well as the speed:

$$\text{Gas Hp.} = (H \times w)/(33{,}000 \times \eta_h) \qquad (9)$$

Gas horsepower includes all the fluid losses. In addition, there are bearing and seal losses which must be added to it to obtain the shaft horsepower. On the average the mechanical losses amount to about 1% of the total power, so that

$$\text{Shaft Hp.} = \text{Gas Hp.} + 1\% \qquad (10)$$

In an actual compressor the head produced by a given impeller's rotation speed is related to the theoretical head by a factor μ called the "pressure coefficient," which has an average value of 0.55. Here:

$$H_h = \mu u^2/g \qquad (11)$$

* Charts of the compressibility factor Z can be found in various thermodynamic texts. Latest compressibility data were given for 30 gases by Nelson and Obert before the 1953 annual meeting of ASME. Their five charts, reproduced large size, appeared in *Chem. Eng.*, July 1954, pp. 203-8.

From this it will be seen that head varies with the square of the gas velocity (i.e., square of impeller speed). An alternate form of Eq. (11) is easier to use for determining rotational speed:

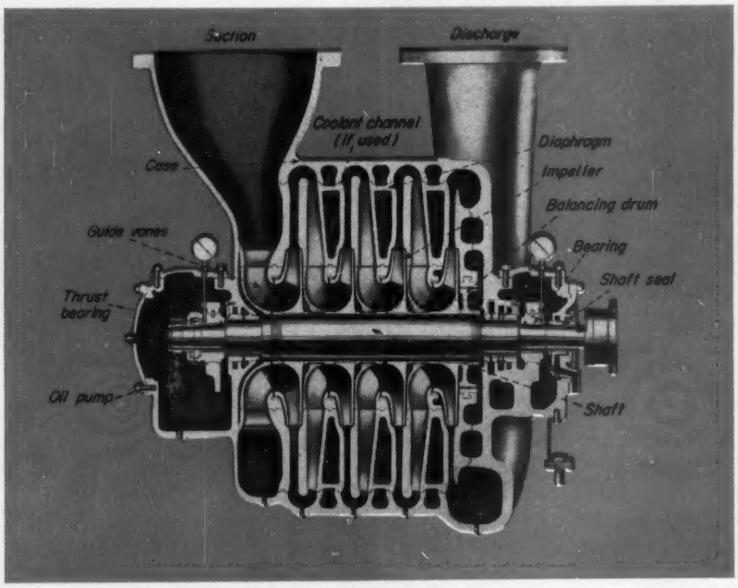
$$\text{Speed, rpm.} = \frac{1{,}300}{D}\sqrt{\frac{H \text{ per stage}}{\mu}} \qquad (12)$$

Present practice proves that a head averaging 10,000 ft. per impeller gives reasonable stability and efficiency. Hence, for a total head of, say, 57,000 ft., a six-stage compressor would be required. This figure is based on the use of closed impellers with backward-bending vanes, and tip speeds usually not more than 800 ft./sec.

Effect of Speed and Diameter

There are a number of general rules on the performance of centrifugal compressors which are useful for the user to know. In a given compressor, change in the speed causes: (1) the head to vary directly as the rpm. squared; the volume flow rate (cfm. at outlet) to vary directly as the rpm.; (3) the cfm. at inlet to vary approximately as the rpm., depending on r; (4) the efficiency to remain constant for small speed variations; and (5) the bhp. (shaft hp.) to vary directly as the rpm. cubed.

In two geometrically similar



Cross section shows construction of typical centrifugal compressor. (Fig. 4)

compressors operating at the same speed, the various flow velocities and peripheral velocities will vary in proportion to the diameters. Then: (1) the ratio of flow volumes will vary as (D_1/D_2) cubed; (2) the ratio of heads will vary as (D_1/D_2) squared; and (3) the ratio of bhp.'s will vary as (D_1/D_2) to the fifth power.

All geometrically similar impellers can be classified hydraulically according to a factor known as the specific speed:

$$\text{rpm.}_{sp.} = \text{rpm.}\sqrt{\text{cfm.}}\ /H^{3/4} \qquad (13)$$

This specific speed can be used as a "type number." It remains constant for all impellers of the same class and does not change with compressor speed changes.

General Characteristics

A characteristic peculiar to a centrifugal compressor is a minimum capacity at each speed below which the compressor operation is unstable. This phenomenon of surge is shown on Fig. 9. At surge the compressor does not meet the pressure of the system into which it is discharging. This causes a cycle of flow reversals as the compressor alternately delivers gas and the system returns it.

Single-impeller compressors have a maximum stable operating range. This range is defined as the percentage of rated inlet volume at constant discharge pressure. The range will decrease approximately 5 percentage points for each additional impeller used, due to the increased volume reduction of multiple stages. Some of the methods for eliminating surge or increasing the stability range include: (1) putting a blow-off valve in the discharge line, (2) providing a bypass line, (3) locating a throttle valve in the system, (4) providing variable inlet guide vanes, or (5) setting up a two-compressor case arrangement, each with its own driver. The molecular weight of the gas influences stability, high molecular-weight gases decreasing and low molecular-weight gases increasing the stable operating range.

Flow in a centrifugal compressor may also encounter a phenomenon of stall. This is usually called "stonewall." (See Fig. 9.) Generally the condition of maximum flow occurs at the eye of the first impeller and cannot increase beyond this point.

Normally the maximum efficiency of the compressor peaks at a capacity condition slightly less than the rated condition. Stable operating range is usually a compromise between efficiency and stability.

Nomenclature

- c_p Specific heat at constant pressure.
- c_v Specific heat at constant volume.
- D Impeller diameter, inches.
- g Gravitational constant, 32.2 ft./sec.^{2}
- H Head of fluid, ft.
- h Total enthalpy of fluid, Btu./lb.
- k Adiabatic exponent = specific heat ratio, c_p/c_v.
- n Polytropic exponent.
- P Pressure, lb./sq. ft. abs.
- p Pressure, psia.
- R Gas constant, 1,545/ mole wt.
- r Compression ratio, p_2/p_1.
- T Temperature, °F. abs.
- U Peripheral velocity of impeller, ft./sec.
- V Gas velocity relative to impeller, ft./sec., in Fig. 5 only; volume, cu. ft.
- v Resultant gas velocity, ft./sec.
- W Work, ft.-lb./lb.
- w Weight rate of gas flow, lb/min. =cfm.×gas density, lb./cu. ft.
- Z Compressibility factor (see *Chem. Eng.*, July 1954, pp. 203–8).
- η_h Hydraulic (polytropic) efficiency.
- μ Pressure coefficient = 0.55 on average.

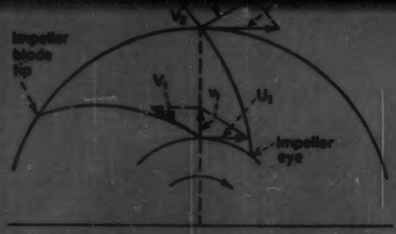
Subscripts

- a Adiabatic.
- h Hydraulic.
- i Isothermal.
- 1 Inlet condition.
- 2 Outlet condition.

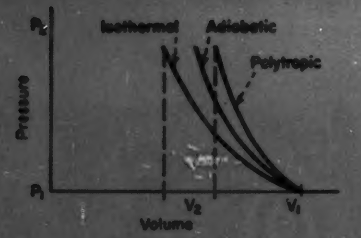
Design Considerations

To meet specific applications many design variations have been employed. For example, both horizontally and vertically split compressor cases are used, depending on the pressure and type of gas. The pressure dividing line is roughly 800 psia.

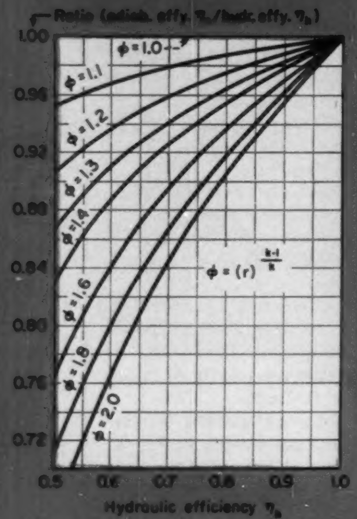
Cooling of the compression process provides many advantages, the most important being power savings and lower discharge temperatures. In some processes, such as those involving oxygen or acetylene compression, maintaining temperatures below maximum values may be necessary for safety reasons. Three methods of cooling may be used: (1) cooling of the diffusers, (2) cooling by means of heat exchangers external to the



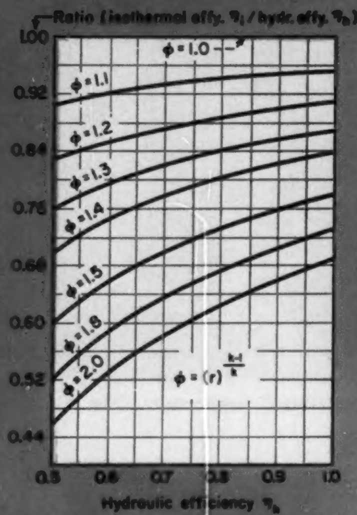
Gas velocities entering and leaving a centrifugal impeller. (Fig. 5)



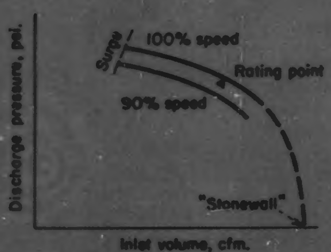
Approximate compression paths on the pressure-volume plane. (Fig. 6)



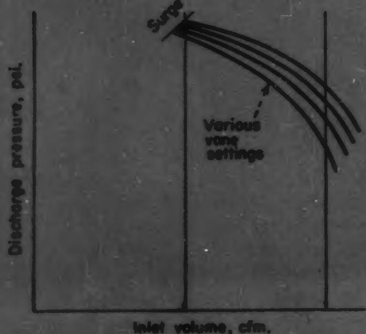
Conversion chart for adiabatic and hydraulic efficiency. (Fig. 7)



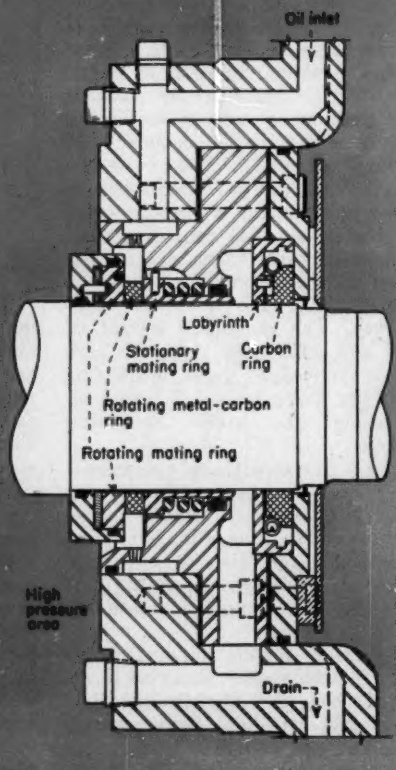
Conversion chart for isothermal and hydraulic efficiency. (Fig. 8)



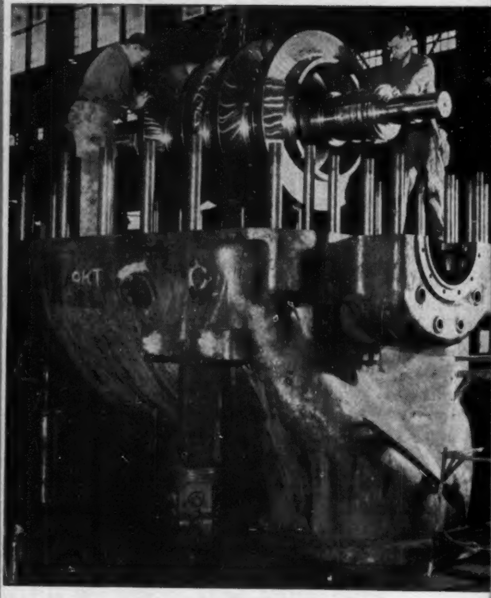
These characteristic curves are typical of performance of centrifugal compressors. (Fig. 9)



Characteristic curves modified by variable inlet guide vanes. (Fig. 10)



Mechanical contact seal is used for minimum gas leakage. (Fig. 11)



Putting shaft and impellers into a large Clark centrifugal compressor.

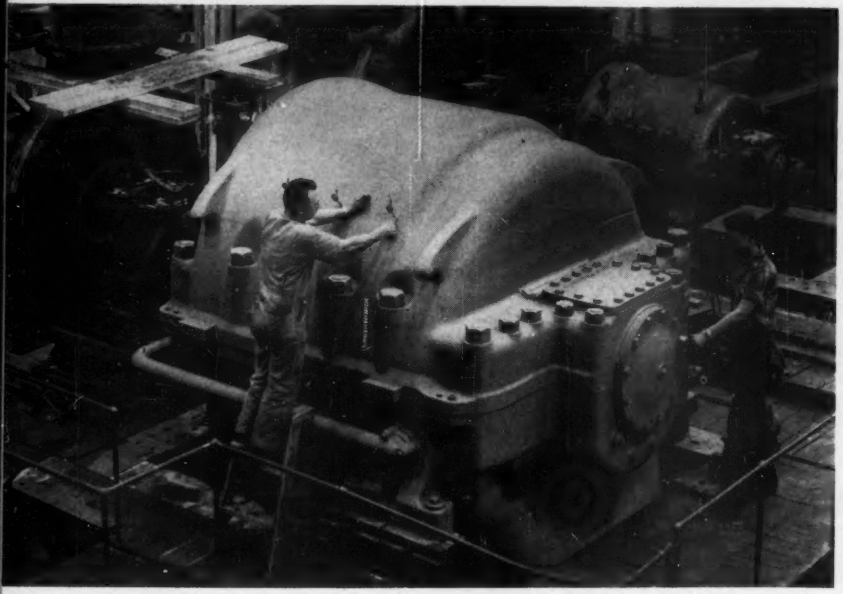
compressor, (3) injection cooling.

Cooling the diffusers, or diaphragm cooling, as it is normally called, is a very common method of internal cooling. Coolant is circulated through the diaphragm passages located between diffusers of adjacent stages. These passages are shown in Fig. 4. Cooling by means of intercoolers also is very common. With this method the compressed gas is led out of the compressor at intervals during compression and returned to the succeeding stages after cooling. The number of steps of intercooling depends on the maximum compression ratio per compressor case, temperature rise of the gas, and the reduction in power desired.

Cooling by injection has not been as common as the other methods. In this method a suitable liquid is sprayed through atomizers into the return channel of a multi-stage compressor. Since weight flow of fluid being compressed will be increased by the amount of cooling liquid added, the power saving is not as great. This method is used primarily to reduce temperature.

Compressor Regulation

In applications having constant-speed drivers, various methods are applied to accommodate varying process conditions. Two methods



Assembled, compressor goes on test stand, driven by radial expansion turbine. Frontispiece shows a diaphragm being installed in this machine.

are (1) use of an inlet or discharge valve, and (2) variable inlet guide vanes. The variable inlet guide vanes modify the pressure-volume performance of the first stage, thereby matching the compressor with the required system characteristics. This method is more efficient than use of a throttle valve. Fig. 10 shows the pressure-volume characteristics with variable inlet guide vanes.

Since compressor requirements are so diversified many methods of shaft sealing are used. The common types include the labyrinth seal, carbon-ring seal, mechanical-contact seal, and oil seal. The labyrinth seal consists of a series of restrictive rings or knife edges to maintain close radial clearances between a rotating element and the case. A small leakage to atmosphere will occur, depending primarily on the pressure of the system. This seal may be modified by the addition of an ejector to eliminate any leakage to the atmosphere. System pressures up to 200 psia. can be handled.

The carbon-ring seal (see Fig. 22, p. 236) employs segmental carbon rings and is generally used in conjunction with labyrinth seals for higher pressures. The mechanical contact seal (Fig. 11) depends on rubbing contact between one or more rotative parts and a fixed member. It is used where minimum gas leakage is desired owing to a relatively expensive gas, and where seal power losses are acceptable. The oil seal (Fig. 23, p. 236) is principally used on high pressures and is being used on compressors up to 2,500 psia. Sealing is provided by introducing a high-pressure sealing oil between the shaft and a sleeve. The seal takes little power.

Compressor Selection

In selecting compressors all factors which affect the design and operating characteristics must be defined and carefully studied. The essential data include such items as gas characteristics, inlet and discharge pressure, inlet temperature, type of driver, driver operating conditions and any special consideration or limitations due to process, surrounding atmosphere or equipment arrangement. Most gases to be handled—other than air—do not follow the ideal gas laws, so additional data should be specified, including the isentropic exponent of compression and the compressibility factor. For high molecular weight gases at high pressures deviation from the perfect gas laws may be appreciable.

A typical selection of an uncooled compressor involves the use of Eqs. (7) to (13).

The speed is determined from the impeller diameter, which is defined by standard frame sizes and head per impeller. For specified operating conditions the polytropic head is the same for all practical purposes and speed may be varied by adding or omitting impellers. Sometimes this is necessary to meet conditions of parallel operation, reducing speed to meet driver conditions, or the handling of high molecular-weight gas.

The compression of gases of very high molecular weight results in large volume reduction. Hence, for such fluids as the Freons, special designs are necessary to maintain reasonable efficiencies and stability.

Installation

Proper installation is essential for satisfactory operation of centrifugal compressors. Minimum foundations are required compared to other types of compression equipment. The type of foundation depends on local conditions but it should be independent of its surroundings. All process and steam piping should be properly supported so as not to place any load on the equipment flanges. This is necessary to maintain alignment. Hot checks should be made.

Normally, bypass lines or blowoff valves are installed to facilitate starting. A check valve should be installed in the discharge line as close to the compressor as possible to protect it from surges. On constant-speed drives, it is necessary to close the inlet valve when starting to prevent over-loading the motor. After the unit is operating it should be brought to stable operating range rapidly to prevent overheating.

Centrifugal compressors are finding wide use due to recent development of dependable and simple seals, the availability of suitable high-speed drivers, and the acceptance of high-speed turbo machinery. An appreciation of the factors affecting design and application will enable engineers better to evaluate the compressor portion of the problem of handling compressible fluids.

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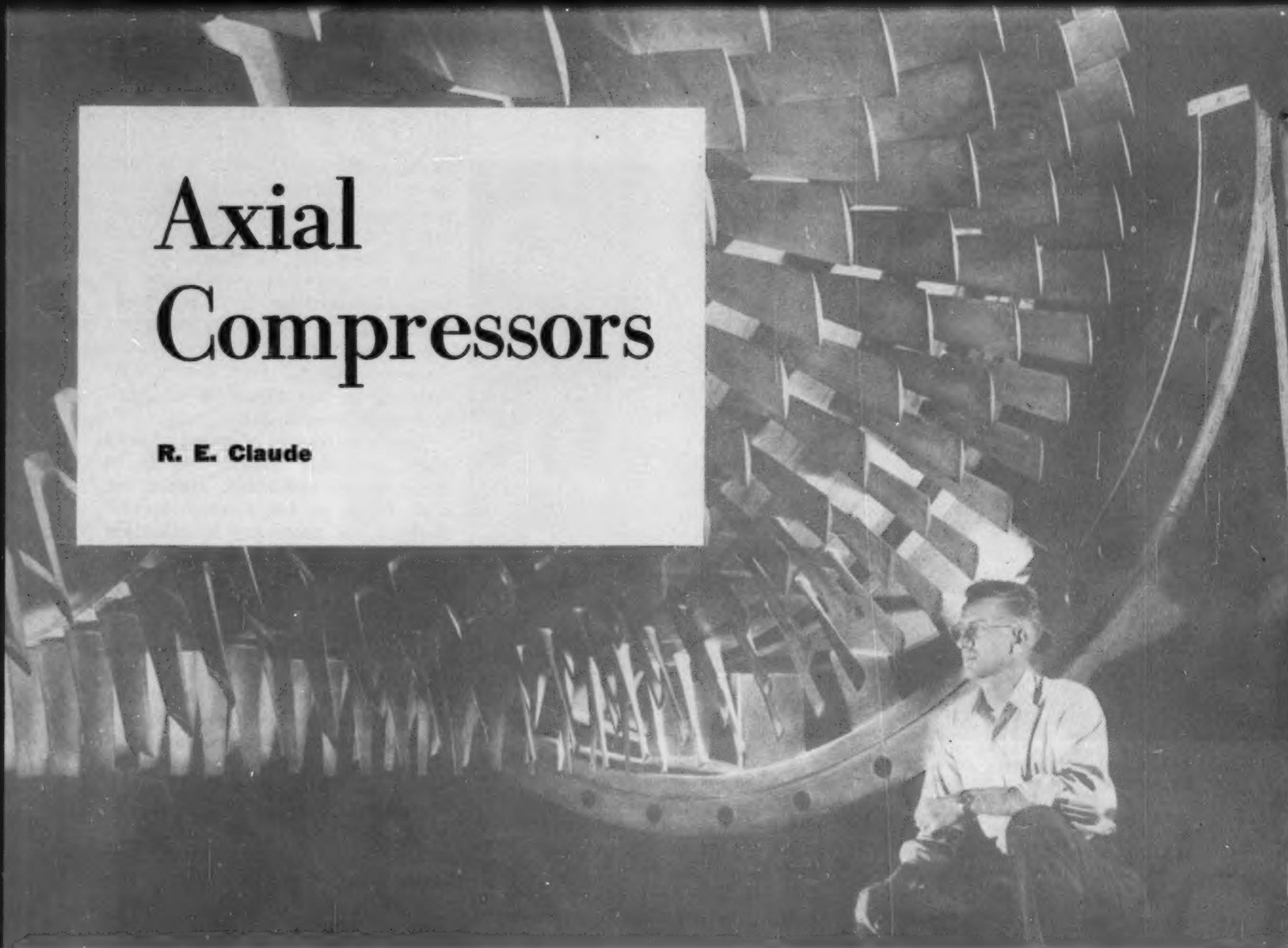


Axial Compressors

R. E. Claude

The axial compressor, although not a new type of compressor, is new in regard to general acceptance for industrial applications. For many years, centrifugal or positive-displacement compressors and exhausters were the only types considered and used. However, in recent years many improvements have been made in basic designs that now give the axial greater scope.

For example, current designs use only two thirds the number of blade rows for a given pressure ratio as were required by early designs. This has been brought about by refinements in blade shapes and designs.

Also, movable stator blades have increased the axial compressor's range so that, for all practical purposes, it approaches the centrifugal. Yet it still produces the higher pressure rises that are peculiar to the axial.

Large inlet volumes required in many present applications have exceeded the capability of the centrifugal compressor, in some cases, thus bringing the high-capacity axial compressor into prominence in the air and gas handling field.

Bristles With Blades

The axial compressor, Fig. 1, is distinguished by the multiplicity of its rotor and stator blades. These are either forged and machined or precision cast into airfoil shapes.

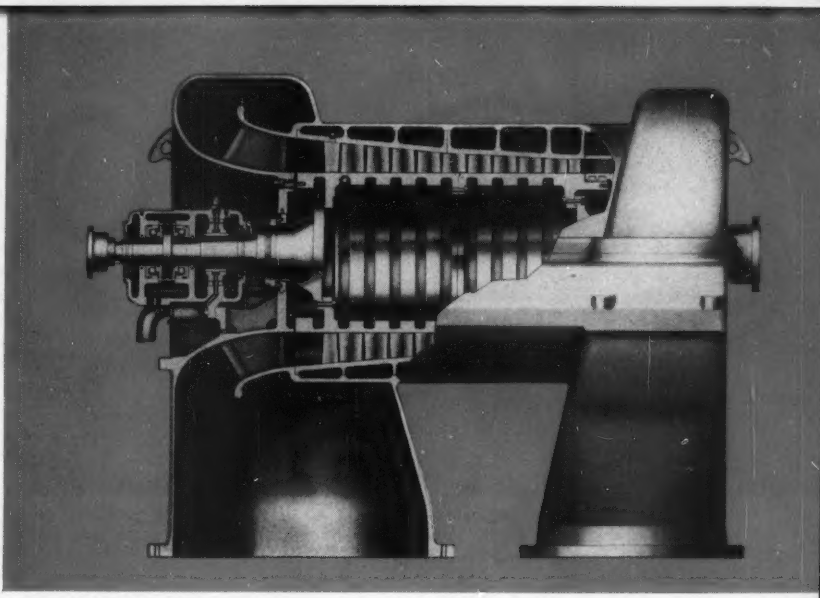
The compressor casing is made of cast iron or fabricated out of steel depending upon inlet volume, pressure ratio and temperature conditions. Inlet and discharge nozzles can be located in a variety of positions: axial, vertical with openings either up or down, side entering and discharging, or combinations of these positions. Most very large axial compressors are built with axial inlet and discharge since nozzle size needed to handle large volumes makes any other nozzle arrangement extremely impractical.

Stator blades can be attached either to the outer casing of large-volume machines, or to separate cast or fabricated cylinder liners which fit inside the outer casing. In either case, these blades have tapered shanks that seat in mating tapered holes in the casing or liner. A threaded root on the blade extends through the hole to engage a nut fastener.

With either type of construction, and particularly with the separate cylinder liners, there is easy access to the rotating assembly or stator blades for inspection or maintenance.

The rotating assembly of small and medium-sized axial compressors is a drum with stub shafts attached to either end. Blades are mounted around the periphery of the drum. Rotor drum is forged in one, two or three pieces which are bolted securely together. The stub shafts then bolt onto each end of this drum.

Rotor blades are fastened to this hollow drum by the same



Rows of moving and stationary blades in axial compressor are precision formed to airfoil shapes. Blade angle is changed to vary capacity. (Fig. 1)

method mentioned for the stator blades. Thus a trained man can adjust these blades at any time to match stages properly or to increase or decrease capacity requirements. He just removes one of the stub shafts for access to the inside of the drum to loosen or tighten the nuts.

For large-volume axial compressors the rotor drum is built up of forged-steel disks welded together. In this case, the rotor blades are fastened to the drum by an integral-root-type blade similar to steam turbine and aircraft jet-engine compressors.

Forged steel stub shafts with highly polished bearing journals incorporate a Kingsbury-type thrust bearing to take the thrust not opposed by the balance piston. The axial compressor does not have a separate balance piston as does the centrifugal machine but has the balance piston machined as part of the rotor drum. The load bearings are similar to those used for other rotating machinery and need not be discussed here.

Fifty-Fifty

Axial compressor design is based generally on the theory of 50% reaction, which means half of the pressure rise is accomplished at the rotor blade and half at the stator blade.

As air flows through the rotating blades both its static pressure and kinetic energy increase. Each row of stationary blades converts kinetic energy to pressure, acting as a diffuser for air flowing out of the preceding row of rotating blades. Also, the stationary blades act as nozzles to guide air into the next row of rapidly revolving rotor blades.

This is analogous to the centrifugal machine. The rotor blade takes the place of the centrifugal impeller wheel and the stator blade can be likened to the diffuser section and diaphragms.

Good design practice for an axial compressor dictates an axial velocity for air in the range from 300 to 450 ft. per sec. For gases other than air, the axial velocity should be proportioned on a Mach number basis. In other words, the axial velocity should be varied by the same proportion as the speed of sound varies for different gases.

In most cases, the compressor is designed to maintain constant velocity from one stage to another. Stage refers to one complete row of rotor blades and its adjacent row of stator blades. Thus, a nine-stage axial compressor has nine rows of rotor blades and nine rows of stator blades.

As the pressure increases through each stage, with a consequent decrease in volume, annular area must be smaller to hold axial velocity constant. This is achieved by tapering either the rotor drum or the cylinder liner.

Desired pressure rise for a given set of conditions will determine the number of stages required. Generally, as a rule of thumb, an axial compressor uses twice the number of stages needed by a centrifugal compressor; an 8-stage axial is comparable to a 4-stage centrifugal.

An axial compressor with modern blade design is limited, generally, to sixteen stages. Allowable temperature rise, depending upon the gas handled and possible structural problems, is usually the limiting factor on the number of stages and consequently the over-all pressure ratio.

The individual range of an axial compressor can be seen in Fig. 4. At part load points, a much greater pressure is produced than by a centrifugal rated at the same pressure ratio.

Handles Largest Volumes

Size of an axial compressor depends upon desired inlet volume. The axial is inherently smaller than an equivalent-rated centrifugal. As inlet volumes go up, the advantage increases for the axial machine.

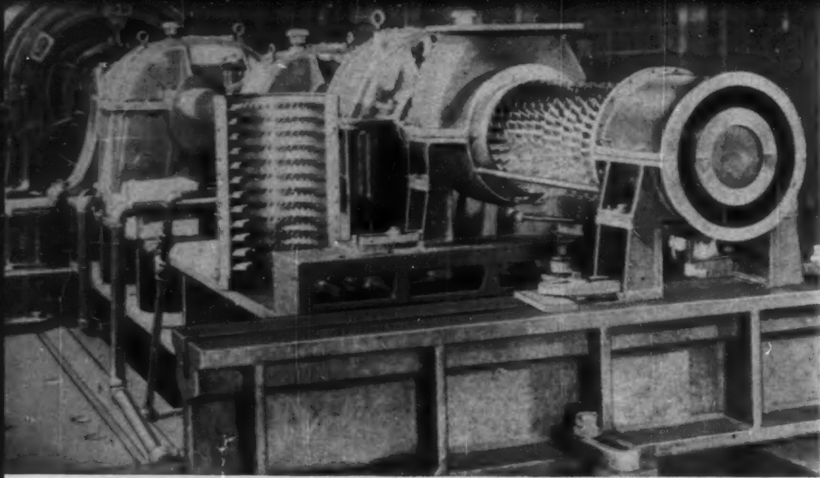
Physically, a 150,000 cfm. axial compressor is approximately one half the diameter of a comparable centrifugal compressor. Above that point, an axial compressor is the most desirable machine for handling all gases, based on the size factor.

Normally, an axial compressor can be designed readily for inlet capacities above 5,000 cfm., but for less than 5,000 cfm. high operating speed usually limits consideration of this machine. In Fig. 2 you see a small-volume, 12-stage machine rated at 8,000 cfm. and 11,500 rpm. By comparison, a 910,000 cfm. unit is shown as the lead illustration for this section. Axial compressors have been built as large as 13 million cfm. and that is still not the highest inlet volume that could be handled by this equipment.

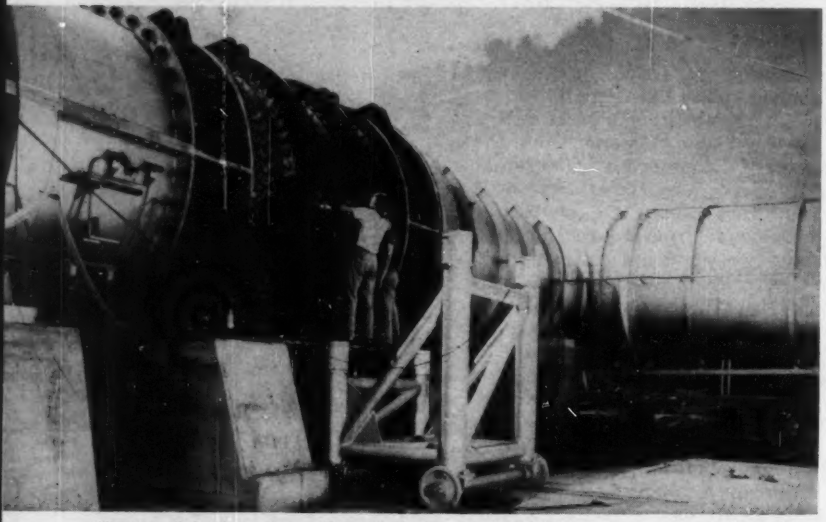
Efficiency is High

The axial compressor has many unique characteristics. For one, efficiency is 8-10% higher than for a comparable centrifugal. This means lower driver horsepower for the axial.

Also, in the larger sizes, the inherently higher speed of the axial may favor optimum operation of the driver, not possible with the centrifugal. For example,



Small, 12-stage axial compressor handles 8,850 cfm. at 2.60 pressure ratio. Machine operates at 11,500 rpm. Case is removed to show rotor and stator blades prior to test stand run. (Fig. 2)



Giant axial compressor for wind tunnel installation is constructed so that section of tunnel serves as compressor casing. This simplifies the piping needed for such a mammoth air-handling facility. (Fig. 3)

where an axial runs at 3,600 rpm., which is an optimum turbine or motor speed, an equivalent centrifugal would run below 3,000 rpm.

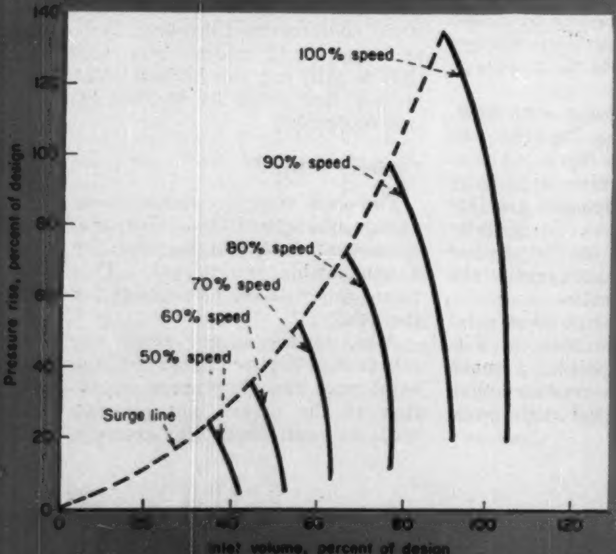
The characteristic horsepower curve of an axial compressor is shown in Fig. 6. For an axial, the horsepower decreases with an increase in inlet volume at a given speed. Also, because of its steeper performance curve (see Fig. 4), with a slight decrease in volume pressure rise increases greatly which makes the axial ideally suited for operation as a base load machine.

Good Team Worker

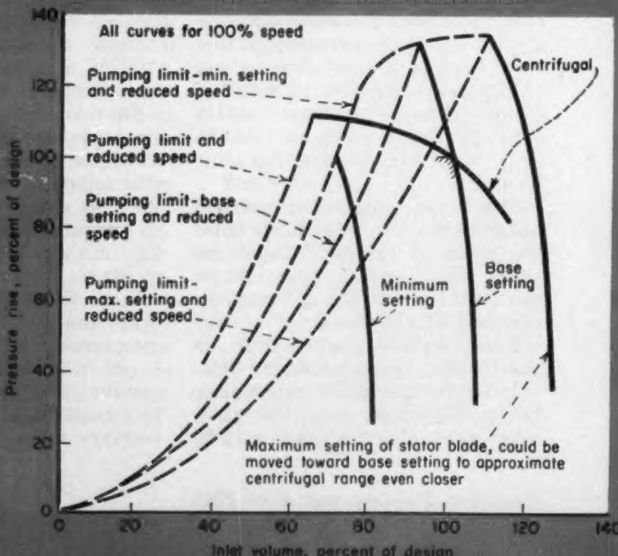
The steep curve of the axial also suits it for parallel hookup with other machines (see Fig. 7). The machines do not need to be matched closely in pressure ratio as is the case when running two centrifugals in parallel. The axial discharge pressure will adjust to that of the parallel machine, and suffer little change in volume of inlet gas.

A wide range of pressures at constant speed and practically constant volume makes the axial fit in nicely with processes which require such a machine. With a turbine driver its performance at variable speed is well suited to meeting varying process demands as they arise.

Performance of axial compressor at various speeds. (Fig. 4)



Stable volume range extended by stator blade control. (Fig. 5)



Like the centrifugal, the axial discharges oil-free air making it a good machine for applications where large volumes of oil-free air or gas are needed. Another unique feature is the simplification of internal sealing. No interstage seals are necessary except on the balance piston end and, of course, the shaft seals.

Some applications demand a wide variation of volume at rated pressure as provided by a centrifugal compressor characteristic. The axial, with fixed blade settings, can operate down to about 85% of rated volume at rated pressure rise. However, stator blade control can be provided on an axial compressor to extend greatly the stable volume operating range, Fig. 5.

This method allows the angle of all or part of the stator blades to be changed while the machine is in operation. This change of blade angle provides a capacity range for the axial compressor that is approximately the same magnitude as available from a centrifugal compressor. The high efficiency characteristic of the axial is not seriously affected with stator blade control.

Flexibility Can Be Built In

Design of the axial compressor can be varied for special applications. For example, inlet and discharge nozzles, as mentioned before, can be set in any combination of positions. In Fig. 3, you see an axial whose casing is a section of a wind tunnel. This simplifies any piping problems which could arise if only vertical inlets and discharges were used on such a large installation.

In cases where plant expansion is expected, an axial can be designed so that stages can be added or removed at a later date for changing pressure ratio. The volume rating can also be varied easily by changing the angles of the stator and rotor blades as discussed previously.

These factors allow the operator to install a machine that will meet his initial requirements. Then, as the need arises he can modify the compressor rating in the field to satisfy process changes.

Optimum performance can be obtained best by operating as close to the rated point as possible. Suction throttling, inlet guide vanes or stator blade control can all add to top performance.

If the pressure drop or system requirements have not been gaged correctly when setting up the compressor requirements, optimum performance can be obtained merely by adjusting blades within the capability of the driver. As a result, off-rated-point operation and consequent lower efficiency can be avoided.

Costs Favorable

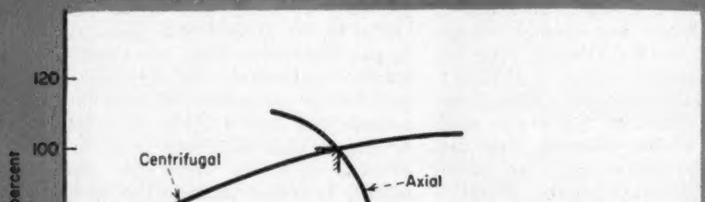
Initial cost of the axial compressor is about the same as that of the centrifugal compressor. Due to higher efficiency the axial can use a smaller turbine or motor, which means lower initial driver cost. Since the axial compressor and driver are smaller and lighter than a comparable centrifugal installation, foundations for mounting these machines are smaller and less costly.

Operating cost is less due to higher efficiency. For large steam-turbine-driven axial compressors many thousands of dollars per year can be saved in steam cost when compared with an equivalent slower-speed centrifugal installation.

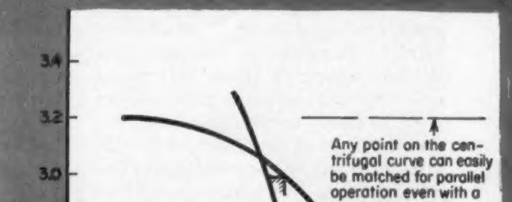
Maintenance is approximately the same as for all types of dynamic compressors. Depending on the usage, the axial compressor should be opened and inspected once a year, if possible. Cleaning is very easy since there are no hidden pockets and all points are reached without trouble.

Blading should be checked and the bearings inspected at this time. All close clearance points are checked to see that they are within recommended tolerances. Over-all, the maintenance procedures common to almost any kind of rotating machinery apply to the axial compressor.

Horsepower characteristic for axial vs. centrifugal. (Fig. 6)

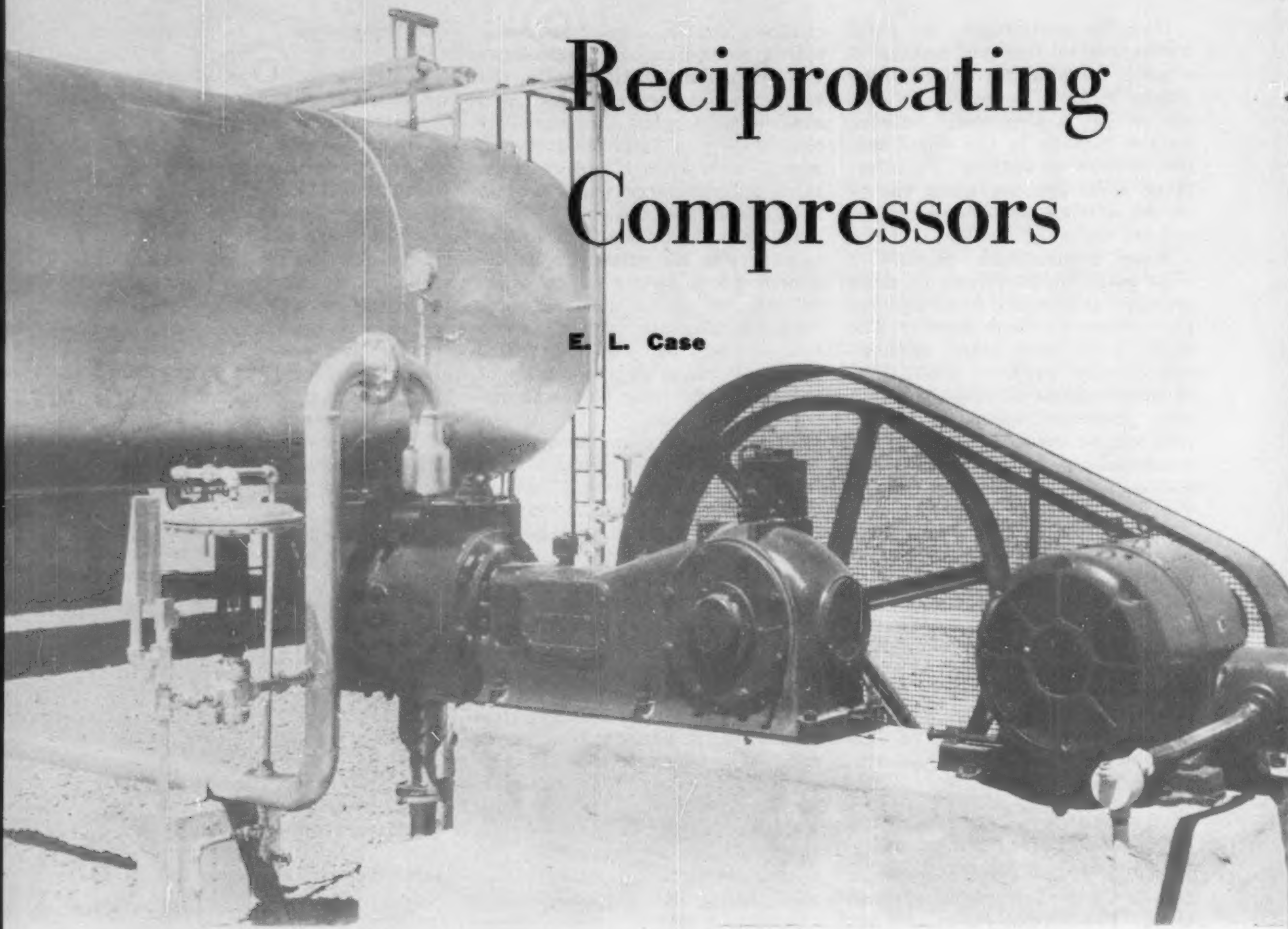


Pressure will adjust to parallel centrifugal. (Fig. 7)



Reciprocating Compressors

E. L. Case



Reciprocating compressors are positive-displacement machines, used to increase the pressure of a definite volume of gas by volume reduction. Most such compressors used in heavy industrial production and continuous chemical processing are stationary, water-cooled, double-acting units. The basic running-gear mechanism is of the crank-and-flywheel type, enclosed in a cast iron frame. The crosshead construction permits complete separation of the compression cylinder from the crankcase, an ideal feature for handling combustible, toxic or corrosive gases.

Generally the cylinder is double-acting, that is, compression occurs alternately in the head and crank ends of the cylinder. The cylinder and its heads are usually water-cooled to reduce thermal stresses and to dissipate a part of the heat developed during compression. Compression rings on the piston seal one end of the cylinder from the other. The piston rod is sealed in the cylinder by highly effective packing and any slight leakage may be collected in a vent gland for return to suction or venting to atmosphere.

Gas being compressed enters and leaves the cylinder through voluntary valves which are actuated entirely by the difference in pressure between the interior of the cylinder and the outside system.

Upon entering the cylinder, the gas may be compressed from the initial to the desired final pressure in one continuous step, i.e., single-stage compression. Alternatively, multi-stage compression divides the compression into a series of steps or stages, each occurring in an individual cylinder. Here the gas usually is cooled between the various stages of compression.

The compression process is fundamentally isentropic (perfectly reversible adiabatic), with certain actual modifications or losses which may be considered as efficiencies related to the isentropic base. Thermodynamic losses within the cylinder, including fluid friction losses through the valves, heating of the gas on admission to the

cylinder, and irreversibility of the process may be grouped under the single term "compression efficiency." Mechanical friction losses encountered in the piston rings, rod packings and frame bearings are grouped under the term "mechanical efficiency." Thus, the over-all efficiency of the compressor is the product of the compression and mechanical efficiencies.

For a given service, the actual brake horsepower requirement of the compressor is normally about 18 to 33% greater than the calculated ideal isentropic horsepower. Or, stated another way, the over-all efficiency of most compressors is in the range of 75 to 85%.

Compressor Application

For large-scale continuous processing, commercial reciprocating compressors are available for the following functions:

1. Compressing economically and safely any gas or gas mixture, including those that are combustible, corrosive or toxic.
2. Maintaining suction pressures as required by the process to values as low as 0.2 in. Hg abs.
3. Accommodating a suction temperature range of −40F. to 150F. with normal metallurgical and lubrication considerations.
4. Developing discharge pressures as high as 35,000 psig. with good efficiency and reasonable maintenance. Even higher pressures are feasible.
5. Accommodating wide variations in process flow and operating pressures, both at suction and discharge.
6. Compressing over a wide range of volumes and pressures, using no lubricant whatsoever in the cylinder. This construction may be essential in special cases where oil contamination of the compressed gas is to be avoided.

Machines to meet such varied and often such severe requirements of the process industries are normally custom-designed for the purchaser's specific application.

Some Basic Arrangements

Machines supplied for chemical processing naturally cover a broad range of capacity, pressure and horsepower, all of these being influenced by the process and size of plant.

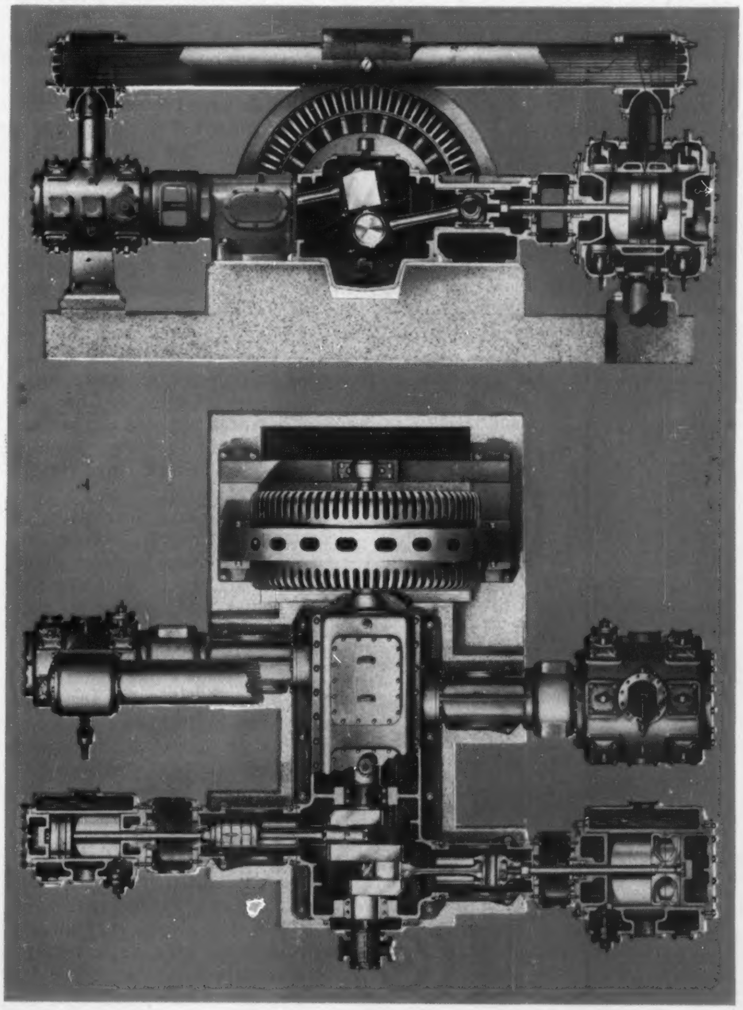
Horsepower ratings of single machines commonly range from 40 to 3,500 bhp., with smaller and larger units occasionally required. Exact arrangements and designs vary considerably with individual manufacturers and only some of the more significant types, together with their more common drivers, are discussed in later parts of this article.

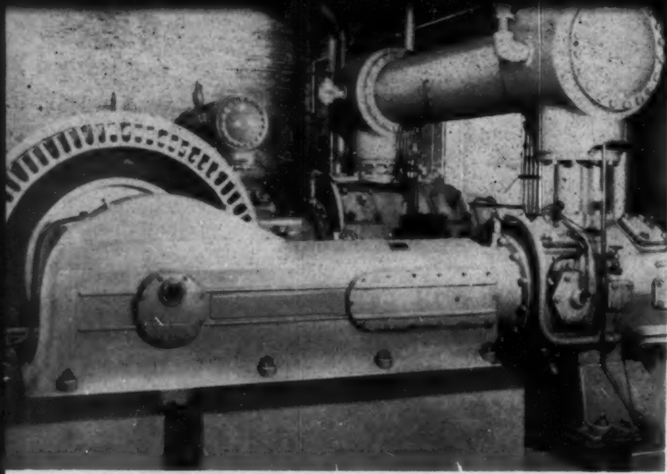
Many units in the range of 40 to 150 bhp. are single-frame machines, an inexpensive design readily adapted to induction motor drive through gears or V belts. The frontispiece shows a typical single-cylinder, single-stage unit driven by a 40-hp. belted induction motor. This single-frame arrangement is also available with integral steam-engine drive, the steam cylinder interposed between the frame and the gas compression cylinder.

For the horsepower range of 40-150, this same basic single-frame design is commonly employed for vacuum service or for multistage compression. In the latter case, for example, cylinders for three stages could be in line, with all of them served by the same piston rod.

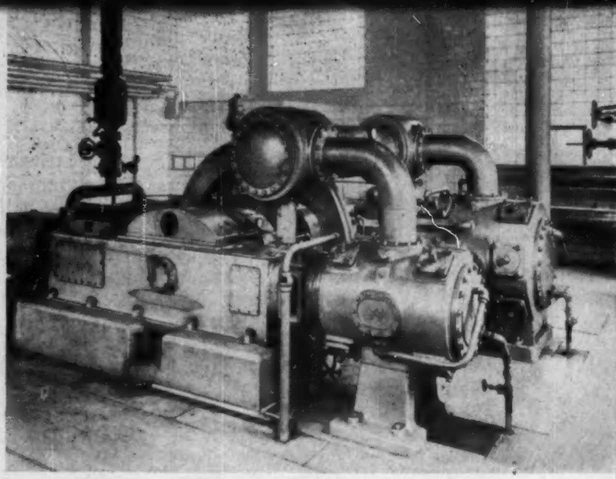
In larger unit ratings, 200 bhp. and up, the type of driver employed greatly influences the arrangement and design of the compressor. However, before discussing various

Four-cyl. horizontal balanced opposed synchronous-motor compressor. (Fig. 1)





400-hp. horizontal duplex two-stage compressor with synchronous motor drive. (Fig. 2)



400-hp. horizontal duplex opposed two-stage compressor with steam-engine drive. (Fig. 3)

drivers, we should note particularly a fairly new type of machine —the horizontal balanced opposed multiple-cylinder compressor shown in plan and elevation in Fig. 1. This is a design which has achieved tremendous popularity in the chemical and petrochemical fields for several reasons.

1. The design has been especially engineered to require a minimum foundation, to conserve space and to permit easy field erection. Thus it reduces field construction and installation costs.

2. Multiple compressor frames (a single machine is readily built with two to eight compressor cylinder stations) permit building several stages of compression—or several compression services—into one machine. Yet the design retains accessibility for operation and maintenance. Such consolidation of services into a single machine appreciably reduces first costs.

3. The crankshaft extension from one end of the frame provides great flexibility in the use of driving equipment. A synchronous or induction electric motor, steam turbine, steam engine or internal combustion engine may be readily employed, thereby giving full freedom in the use of available power or fuel.

4. Intercoolers and interstage piping may be conveniently mounted over the cylinders and fabricated into the machine by the compressor manufacturer, thereby greatly reducing field piping costs.

Compressor Drives

Electric—Larger electric-driven units often employ low-speed, engine-type synchronous motors as drivers, with the motor rotor mounted directly on the crankshaft.

Two basic compressor arrangements are commonly used for this type of drive — the horizontal balanced opposed type (Fig. 1) and the horizontal duplex (Fig. 2.). The duplex is essentially a longer stroke, slower rotative-speed machine than the balanced opposed. Representative duplex speeds are 150 to 300 rpm., compared with 300 to 600 rpm. for opposed units. The duplex is often used for single- and two-stage compression where low rotative speeds are indicated, for example, in lime-kiln gas compression.

For hazardous atmospheres, the engine-type synchronous motor may be fitted with various enclosures but it is not available in explosion-proof construction. Consequently, some users prefer explosion-proof induction-motor drivers. The horizontal balanced opposed compressor is ideal for coupling to such induction motors, either directly or through a gear set.

Above 1,500 hp., practically all electrical installations employ engine-type synchronous motor drive.

Steam — Larger steam-engine driven units are generally horizontal duplex machines, with reciprocating steam cylinders mounted on one end of the duplex frame and compression cylinders on the opposite end, as in Fig. 3.

Such units possess the advantages of good steam economy over a wide range of speed, load and steam pressures, broad capacity variation through speed control and ease of operation and maintenance.

A very significant development in recent years has been the successful use of the steam turbine and speed-reducing gear as a reciprocating compressor driver (Fig. 4). This has been made possible by the development of the horizontal balanced opposed compressor, greater knowledge of torsional systems, and advances in coupling design. Thus, today, the chemical engineer can secure the economic advantages and flexibility of the horizontal opposed compressor, together with oil-free steam from the turbine exhaust.

Gas—The most significant internal-combustion engine driven compressor remains the integral angle design, almost always built as a spark-ignition gas engine as in Fig. 5. Within the past few years, exhaust turbo-charging has been very successfully applied to this design with resulting reduction in installation cost per unit horsepower, reduction in operating noise

Definitions

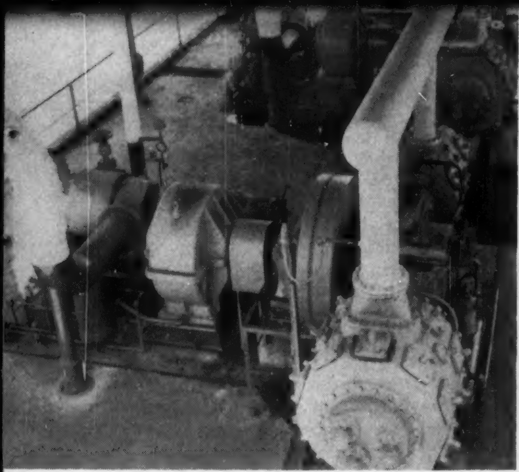
Some fundamental definitions commonly employed in reciprocating compressor practice are:

Piston Displacement—Net volume actually displaced by the compressor piston at rated machine speed, generally expressed in cubic feet per minute. For multi-stage compressors, the piston displacement of the first stage only is commonly stated as that of the entire machine.

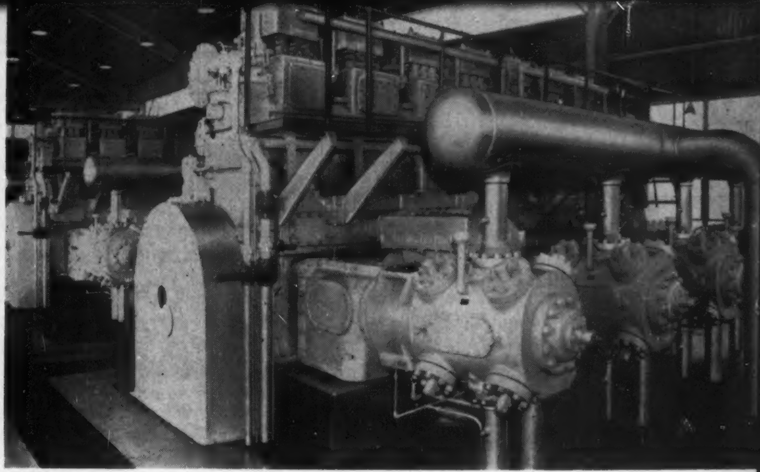
Actual Capacity—Quantity of gas actually compressed and delivered to the discharge system by the machine at rated speed and under rated pressure conditions. Expressed in cubic feet per minute at first-stage inlet gas conditions.

Volumetric Efficiency—Ratio of actual capacity to piston displacement, stated as a percentage.

Compression Efficiency—Ratio of calculated isentropic work requirement to actual thermodynamic work re-



400-hp. balanced opposed two-stage compressor with steam turbine drive. (Fig. 4)



Group of 1,400-hp. integral angle-type single-stage compressors driven by spark-ignition gas engines. (Fig. 5)

and substantially improved fuel economy. Commercial turbo-charged gas-engine compressors are now available with a brake thermal efficiency of 35%, and better.

Occasionally, the economics of the available fuel supply warrants coupling the horizontal balanced opposed compressor to a vertical diesel or dual-fuel engine. In comparison with the integral angle gas-engine design, this combination has the disadvantage of higher initial equipment price, higher installation cost and greater floor space requirement.

Selection of the type of compressor drive is fundamentally a matter of basic economics, revolving about the anticipated duration of the process, the cost of power or fuel, initial equipment and installation costs, and expected maintenance charges. Secondary but important considerations are flexibility of the driver to meet process demands, and availability of required operating and maintenance personnel.

Design Variations

Fundamental to the approach in reciprocating compressor design is the development of a line of standard frames. Then, for use with these standard frames, specific cylinders are built to meet the demands of individual applications. Thus we find great variation in compressor cylinder design and arrangement. Some of the considerations involved and some of the designs employed in various types of chemical processing will be discussed.

For High Pressure

Reciprocating compressors are essential to many processes operating at 2,500-35,000 psig. They are used in large numbers in the production of synthetic ammonia, methanol, urea and polyethylene, and in various hydrogenation processes.

In considering the compression requirements of a high-pressure process, the chemical engineer should remember that the work of compression is an exponential function of the discharge pressure. Hence, the increased work is less than proportional to any discharge pressure increase. For example, to compress a given volume of hydrogen from atmospheric pressure to 12,000 psig. requires only about 15% more work than to compress the same volume from atmosphere to 6,000 psig. Six-stage compression is here assumed for either discharge pressure.

Also, the effect of compressibility on the gas volumes to be handled at high pressures is usually very great and should be considered even in preliminary calculations. Thus, the piston displacement of a recirculator compressor taking suction at 14,000 psig. in a synthetic ammonia process must be about 80% greater than the ideal gas laws would indicate.

Mechanical considerations include the number of stages of compression, rotative and piston speeds and the arrangement, alignment and cooling of high-pressure operating parts.

In addition to influencing the efficiency of the unit, the number of stages affects considerably the gas temperature rise in the individual cylinders and the differential pressure across each stage of compression. The greater the number of stages, the lower the gas temperature rise and the smaller the differential pressures. Lower operating temperatures result in reduced thermal stresses and generally better lubrication. They also reduce the possibility of hydrogen penetration of materials in those units handling hydrogen.

Smaller differential pressures across the individual stages reduce the unit pressures which the valves and piston rings must contain. Of course, the greater the number of stages, the more expensive the machine, and each application must balance the foregoing with the economics of the installation.

Rotative and piston speeds must be carefully considered in the light of the arduous service imposed on the valves, rings and packings by the dense, high-pressure gas. Speeds

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quirement within the cylinder, the latter as determined from the cylinder indicator card. Usually expressed as a percentage, the compression efficiency accounts for all thermodynamic and fluid friction losses.

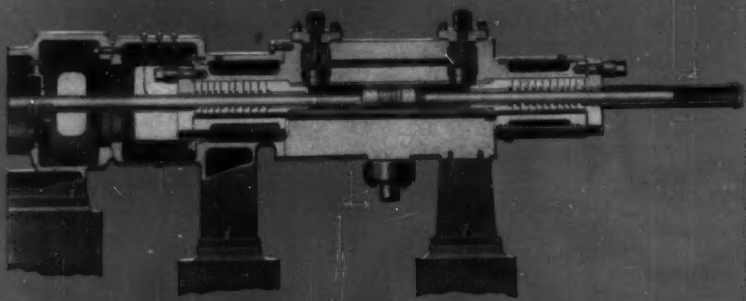
Mechanical Efficiency—Ratio of thermodynamic work requirement in the cylinder (as shown on the indicator card) to actual brake horsepower requirements. Expressed as a percentage, mechanical efficiency takes account of mechanical friction losses.

Compression Ratio—Ratio of absolute discharge pressure to absolute suction pressure. May be applied to the entire machine or to the individual stages of compression.

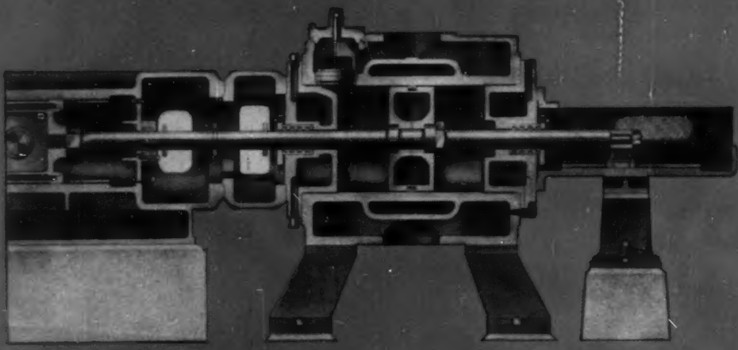
Clearance—Volume present in the actual cylinder in excess of the net volume displaced by the piston during one complete revolution of the machine. Usually expressed as a percentage of the displaced volume.

Typical Speeds of High-Pressure Reciprocating Compressors

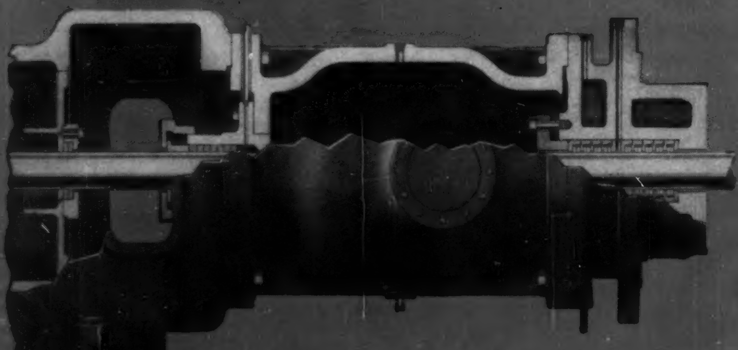
Avg. of Inlet and Discharge Pressures, Psig.	Service	Cylinder Function	Speed, Rpm.	Avg. Piston Speed, Fpm.
1,900	Nitrogen	Last stage of primary gas compressor	320	853
2,700	Hydrogenation	Last stage of primary gas compressor	240	720
3,500	Ammonia synthesis	Last stage of primary gas compressor	300	800
5,000	Ammonia synthesis	Recirculator	200	633
6,800	Ammonia synthesis	Last stage of primary gas compressor	200	535
8,700	Ammonia synthesis	Recirculator	200	400
14,500	Ammonia synthesis	Recirculator	125	177



Cut-away view of ammonia synthesis recirculator compressor cylinder. (Fig. 6)



Cut-away of non-lubricated compressor cylinder with tailrod support. (Fig. 7)



Sealed housing for leakage control situated between frame and cylinder, at right. (Fig. 8)

which are entirely practical for the compression of air to 100 psig. may well result in excessive maintenance of the high-pressure compressor. It is difficult to generalize on proper operating speeds since the size of the unit, operating pressures, design characteristics, and cooling of high-pressure parts all have definite bearing.

One of the prime problems is dissipation of the heat developed in the high-pressure piston-rod packings. This heat generation depends greatly on the average of the suction and discharge pressures under which the cylinder is operating, the rotative speed and, to a lesser degree, the average piston speed. Recirculator compressors used in catalytic processes are particularly acute in this respect, since they operate with sustained high pressure on both the suction and discharge strokes. The general practice is to operate recirculators at as low speeds as are economically feasible.

Listed in the tabulation are some typical rotative and average piston speeds of specific cylinders employed today.

Balanced loading of the compressor frame on both head- and crank-end strokes is another important aspect of high-pressure design. Owing to the small volumes handled, high-pressure cylinders are comparatively small in diameter and are often made single-acting. It is important that such cylinders be arranged to avoid a heavy unidirectional loading on the frame bearings during the entire rotation since such a loading can have a serious effect on the mechanical operation of the bearings, particularly the crosshead pin bearings.

Another aspect is that of operational alignment of the high-pressure parts. Any lateral movement of the piston rod as it travels through the high-pressure piston-rod packing is apt to abrade the packing. Any abrasion generally results in failure of the packing and damage to the piston rod.

Also, adequate cooling of high-pressure packings and piston rods to dissipate the heat of friction developed in these parts is of great importance.

Fig. 6, a section view of a modern ammonia synthesis recirculator compressor cylinder, illustrates how these aspects are incorporated in a given design. The

cylinder is 7 in. diam. by 12 in. stroke, designed to compress approximately 37 million scfh. of unconverted ammonia synthesis gas, when operating at 200 rpm., with 8,400 psig. suction and 9,000 psig. discharge pressure.

The cylinder is fitted with a 3¾-in. diam. piston rod and tailrod. Thus, the resulting load on the piston rod and frame bearings is of the same magnitude, but opposite direction, on the head-end and crank-end strokes. This greatly assists the lubrication system in maintaining the oil film in each entire bearing. A further important benefit of this construction is a more uniform torque effort required of the driving apparatus.

To secure and retain permanent operational alignment, the piston-rod and tailrod packing boxes are forged and machined integrally with the forged steel cylinder block. Also, piston, piston rod and tailrod are a one-piece steel forging. The piston rod and tailrod are supported by a bronze bearing in the bottom of each packing box, this design guiding and steadying the travel of the rods through the packings. The piston rod is joined to the crosshead with a floating connection thereby making the two support bearings in the packing boxes the only points of positive alignment of the piston and rod forging. The large-diameter piston rod minimizes deflection, which further provides for most satisfactory packing performance.

Packings are full-floating and vented, of segmental metallic construction, the type commonly used in high-pressure machines. Because of the high operating pressures, the packing cases on this unit are machined for the continuous circulation of cooling oil, to dissipate the very considerable heat of friction developed in the packings. Additionally, the one-piece rod forging is internally drilled along its axis for the free circulation of cooling oil. An external pump and oil cooler provide the cool oil which is continuously circulated through the packings and rod.

Where Lubrication Is Excluded

Another interesting type of process compressor which particularly illustrates flexibility of application is the non-lubricated unit, Fig. 7. A number of gases and processes cannot tolerate, or at least preferably avoid, the use of hydrocarbon lubrication in the compressor cylinder. Oxygen compression is a prime example of this requirement which is met by fitting the compressor cylinder with piston rings and packing rings which require no lubricant whatsoever.

It is well to recognize that the non-lubricated unit is a solution of a difficult process requirement at the expense of the compressor. Therefore, more maintenance of the piston rings and rod packings should naturally be expected. To minimize this added maintenance, it is sometimes advisable to invest additional money initially to secure a very conservatively designed machine, operating at low rotative and piston speeds. Further, it may also be advisable to employ more stages of compression than on a comparable oil-lubricated unit. This will reduce the differential pressures imposed on the non-lubricated piston rings and prolong their life.

Most non-lubricated compressors operate at discharge pressures below 700 psig., often well below. At higher pressures, maintenance problems and costs usually dictate the use of conventional oil-lubricated compression machinery, with removal of oil from the gas after compression. Further, if the gas to be compressed is bone dry, wear of the non-lubricated rings and packings may require adjustment and change so frequently as to interfere with the economic operation of the process. Many times, humidification of a dry gas before compression is recommended to improve ring and packing life.

Non-lubricated piston rings and packings are generally of pressed carbon, a reasonably inexpensive and good wearing material. However, much study is now being made of various plastics and synthetics as a possible improvement over carbon for certain applications. One of the major design problems is to prevent metallic contact between the piston and the non-lubricated cylinder bore. Smaller-diameter pistons are usually an assembly incorporating carbon rider rings which ride on the bore of the cylinder and support the piston.

The weight of larger pistons is often taken completely off the cylinder wall by the use of a tailrod support as shown in Fig. 7. Further, this drawing illustrates a construction which eliminates even the slightest oil contamination of the gas being compressed. The piston, being completely supported by the main and outboard crossheads, does not come in contact with the bore of the cylinder. Piston rings and rod packings are carbon, requiring no lubrication. The outboard crosshead shoe is carbon, so no oil or grease need be used in the tailrod support. To prevent possible oil carry-over from the crankcase, a special long distance-piece is inserted between the frame and cylinder so that no portion of the piston rod enters both the carbon packing and the oil-lubricated crankcase. Further, a collar on the piston rod in the distance-piece prevents oil from creeping along the rod from the crankcase to the cylinder.

For Corrosive or Toxic Gases

Since a reciprocating-compressor cylinder is entirely separate from the frame, the problem of handling corrosive gases is confined to the cylinder.

The selection of cylinder materials and fittings for corrosive-gas service must be tempered by the wearing and fabricating qualities of available materials. For example, an ideal material from the viewpoint of corrosion resistance might be too soft to serve as a valve seat, or very difficult to cast into a compressor cylinder with its complex internal cores and changes in section.

Compressor cylinder materials are generally selected for strength, the material selection being dependent on the diameter and design pressure of the cylinder. Commonly employed materials are cast iron, cast carbon steel and forged carbon steel. When employed, cylinder liners are generally low-alloy cast iron. Pistons are usually cast iron, fitted with cast iron, bronze or Micarta rings. Ring materials are selected primarily from the viewpoint of compatability with the cylinder bore material, rather than corrosion resistance.

Piston-rod packings are also cast iron, Micarta or bronze, the materials again selected primarily for good operation on the rod. Piston rods of Type 410 stainless steel are satisfactory for many mildly corrosive conditions. In cases of severe corrosion, a very high-nickel-

content rod is sometimes the superior selection. Valves of Type 410 stainless steel often combine good mechanical properties with adequate corrosion resistance. Valve seats and guards of alloyed cast iron and of carbon steel or Type 410 stainless steel are commonly used in chemical processing units with good results.

A fundamental approach to control of corrosion in most compressor cylinders is to keep moisture entrained in the suction gas from entering the cylinder and to prevent the formation of condensate within the cylinder.

Still another important consideration in corrosion control is the sealing of the piston rod in the cylinder. Since the rod is traveling in and out of the corrosive atmosphere, there is the possibility of contamination of the crankcase oil and also of the rod picking up atmospheric moisture and depositing it in the cylinder.

Contamination of the crankcase oil is easily prevented by inserting a distance-piece between the cylinder and the frame as in the case of oil carry-over prevention in nonlubricated compressors.

The piston rod may be prevented from traveling into the atmosphere and into the corrosive gas zone by the installation of a sealed housing between the cylinder and the frame, as shown in Fig. 8. Since the cylinder piston-rod packing is fitted with a vent to catch any leaking gas, the sealed housing may be pressurized with an inert, dry gas such as nitrogen. The housing is made sufficiently long so that no portion of the piston rod travels from the corrosive zone into the atmosphere. In itself, this construction also protects against crankcase contamination.

Handling Toxic Gases

In the case of toxic gases, many users prefer not to depend solely on the vent in the cylinder packing to prevent leakage to the operating room and they specify the sealed housing shown in Fig. 8 to serve as an additional catch basin. In such cases the housing may be fitted with an exhauster to maintain vacuum of a few inches of water column in the enclosure.

Sometimes combinations of sealed and open housings or distance-pieces are employed. The sealed housing itself may be divided into two compartments, the compartment immediately adjacent to the cylinder being used to catch and vent leaking gas from the cylinder, with the next compartment pressurized with inert gas.

Vacuum Pumps

Vacuum pumps are another variant of the reciprocating compressor. Operating with a closed system on the suction side, they readily maintain high vacuums in continuous processing, while discharging at atmospheric or slightly higher pressure.

They may be designed to handle any gas and can be arranged for use with any of the drivers conventionally used with compressors.

While they may be considered as essentially low-pressure compressors, they possess certain unusual design and performance characteristics as a consequence of the somewhat peculiar service conditions imposed upon them.

Suction pressures of 0.5 to 5 in. Hg abs., with accompanying discharge of 30 in. Hg abs., and higher, are commonplace. Thus, the vacuum pump is required to pump a reasonable capacity when operating against compression ratios ranging from 6 to 60. Since the volumetric efficiency of the pump handling a given gas is a function of the clearance in the cylinder and the ratio of compression against which the pump is operating, it is essential that the cylinder clearance be minimized.

To obtain low clearance, the designer uses fewer valves and less valve area than in a comparable compressor cylinder. The resulting higher gas velocity through the valves is of little significance, since total fluid-friction losses are small owing to the very low density of the gas at vacuum conditions.

A second characteristic is the ability of the vacuum-pump cylinder to work against a high compression ratio without injurious heating of the gas or the cylinder parts. Compression ratios that would be unthinkable in a single-stage air compressor because of heating are comfortably handled in the vacuum pump. This also comes from the low density of the gas which results in a comparatively light heat load on the cylinder cooling jackets.

Single-stage vacuum pumps are commonly used for absolute suction pressures of 1.5 in. Hg and higher. For lower absolute pressures, the pump is generally made two-stage since the volumetric efficiency of the single-stage pump becomes so poor at such high compression ratios.

Two-staging may be accomplished in an interesting manner. A double-acting cylinder is arranged with a special outboard head so that the head end of the cylinder serves as the first stage, and the crank end as the second stage. The 1 to 1 cylinder ratio has the effect of causing the first stage of compression to operate with only a low compression ratio. Thus the overall machine volumetric efficiency is high. Although the displacement of the double-acting cylinder so arranged for two-stage operation is only half that of the same size cylinder made single-stage, under high vacuum the resulting capacity of the two-stage machine is greater than that of the single-stage vacuum pump.

No intercooling is needed on two-stage machines, even under the highest vacuums, because of the comparatively low temperature increase of the gas.

Variable Capacity Controls

An interesting and valuable characteristic of the reciprocating compressor is its flow flexibility and adaptability to process control. The operational stability of the modern machine, together with new developments in governors and control devices, makes it possible to integrate the compressor in the process control system, thereby obtaining the highly desirable combination of maximum product quality and minimum production cost.

For control purposes, compressors may be classified as constant-speed or variable-speed machines. Constant-speed compressors are often provided with automatic capacity control by means of a diaphragm-operated automatic bypass valve between discharge and suction lines. Automatic suction throttling is sometimes suggested but is not recommended because of gas over-heating during compression, as well as excessive column loading of the piston rod due to the high differential pres-

sure between suction and discharge.

Suction valve unloaders and clearance pockets are the most common and most efficient methods used. With these devices it is usual to provide two-, three- or five-step unloading, e.g., at 100 or 0% of capacity, 100, 50 or 0% of capacity, or 100, 75, 50, 25 or 0% of capacity. Step unloaders of these types can be controlled either manually or automatically.

With variable-speed compressors, the speed of the steam-engine or gas-engine driver may readily be varied during operation. Characteristics of these units suit them particularly well to integration into process control systems. Speed variation from 100 to 25% is common with steam engines, and from 100 to 50% with gas engines. Such control gives high energy economy since the fluid friction losses in the compressor decrease at lower speeds, while engine economy remains high under these conditions.

(Compressor control is dealt with in detail in the article on Drivers, Control and Accessories on p. 227—*Editor.*)

Installation and Operation

Essential to the successful operation of any compressor is an adequate foundation designed for the specific soil conditions, capable of accommodating the mass and the shaking forces and couples inherent in the reciprocating mechanism.

Vital also are proper supports for the individual cylinders and for the gas piping. Care should be exercised that no strain is imposed on the compressor cylinders by the piping. The gas piping should incorporate provision for expansion and contraction and also sufficient surge capacity to accommodate the pulsating gas flow without excessive pressure variation in the system and with minimum vibration of the piping.

There are certain other considerations also which are extremely important in chemical processing compression machinery.

Clean Piping—Foremost among these is the need for clean process piping on start-up. Dirt, welding scale, shot and other abrasive foreign material are readily carried over into the cylinders and there can cause great damage to cylinder bores, pistons, valves, rods and packings. It is good practice to plan specifically for the cleaning and inspection of all process piping before start-up. Excellent chemical cleaning procedures, which are carried out at the job site, may be purchased at low cost and may well be considered.

Keeping Liquid Out—Keeping liquid out of the cylinder is another very important consideration. Liquid carry-over washes away lubrication and promotes rapid wear of the cylinder, piston rings and valves. Further, liquid can often accelerate corrosion. Slugs can severely damage the unit.

The best safeguard against liquid carry-over is an adequate knock-out drum or trap in the suction line, close to the cylinder. Furthermore, the intake piping should be carefully designed to avoid loops or pockets where condensate might collect and be pulled into the cylinder as a slug.

The gas entering the cylinder may be dry but saturated so that condensation can occur within the cylinder if jacket water temperature is below the dewpoint of the entering gas. Good practice with such gases is to maintain the entering jacket water temperature 10 to 15 F. above the saturation temperature of the entering gas. In many cases of hydrocarbon gas compression, operating pressures and temperatures permit operation without forced circulation of cooling water through the cylinder. Generally a closed system is recommended in which the jacket is filled with water, ethylene glycol or oil, and a small expansion tank is provided. The jackets and piping are arranged to permit thermal circulation of the coolant.

Such an arrangement has the virtue of equalizing thermal stresses in the cylinder and maintaining jacket temperature high enough to avoid condensation of incoming gas. In extreme cases the suction gas is sometimes heated before it enters the cylinder. This is rarely done since heating increases the volume to be compressed and consequently raises compressor horsepower requirements.

Whenever possible, cylinders should be piped to facilitate the ejection of any liquid. For example, horizontal cylinders handling wet gases should preferably be piped with suction on top and discharge on the bottom of the cylinder.

Lubrication—Many of the hydrocarbon gases have an affinity for lubricating oil and care must be taken to insure that valves and cylinder bore are adequately lubricated. While various lubricants such as castor oil and glycerine have been tried, sometimes with success, the most satisfactory approach is usually the use of a heavy stock mineral oil. To insure adequate lubrication, fairly frequent inspection of the valves and cylinders of a hydrocarbon-gas or high-pressure unit is recommended. When gases are wet or saturated, a compounded oil is often helpful.

Valve Service—Fundamental to good valve service is clean, dry gas. Dirt and other foreign matter can readily cause valve strip or plate breakage. Liquid washes away lubricant, often causing rapid wear.

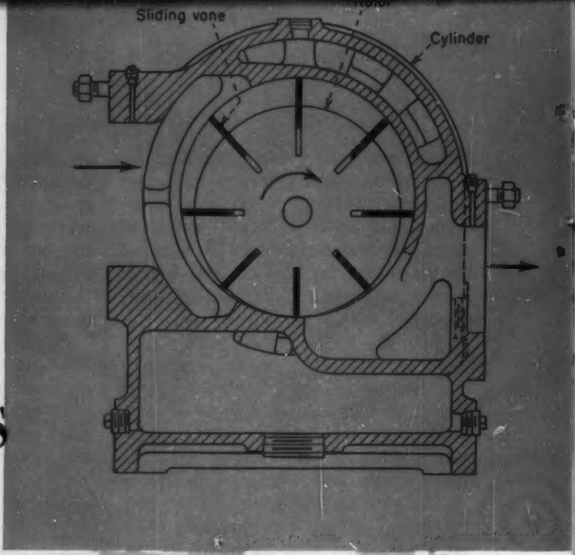
From the viewpoint of corrosion, it is unfortunate that valve materials which have good mechanical properties of strength, hardness and fatigue resistance often show poor resistance to corrosion. Conversely, highly corrosion resistant materials often exhibit inferior mechanical properties. Thus, a specific application may require experiment to determine which valve materials are best and most economical.

Preventing Deposits

On some installations handling hydrocarbon gases, deposits accumulate rapidly on the valves, requiring frequent cleaning. In some cases, considerable relief may be obtained by periodically injecting a considerable quantity of light oil into the cylinder suction port. Such a stream of oil will often wash away much of the deposit. Similarly, on lime-kiln or other dirty gas applications, a quantity of water may be intermittently injected into the suction port to wash away large quantities of dirt which inevitably accumulate on the valves. Water injection must be carefully controlled and combined with lubrication to minimize the detrimental effects of water on the valves and cylinder.

The Operating Log—To obtain satisfactory service from any unit, there is no substitute for periodic inspection and planned, preventive maintenance. To this end, a complete and thoughtfully analyzed log of daily operation is invaluable.

Rotary Compressors and Vacuum Pumps



Sliding vanes form variable compression pockets. (Fig. 1)

W. L. Bruce and W. A. Schubert

It has been interesting to note the increasing use of the principle of rotary compression. Since the turn of the century it has grown from infancy to a major type of compression.

The rotary compressor with its continuous motion is the logical outcome of the modern trend in industrial design. Action of the rotating elements confines successive volumes of air or gas within a closed space and compresses them, which characterizes these designs as positive-displacement units.

General Description

Rotary Sliding Vane—These compressors and vacuum pumps have longitudinal vanes which slide radially in a rotor mounted eccentrically in a cylinder. The rotor is supported at each end by anti-friction bearings mounted in the heads, which in turn are bolted and doweled to the cylinder, Fig. 1.

Rotary Lobe—Compressors and vacuum pumps of this type have two mating lobed impellers which revolve within a cylinder. Timing gears, mounted outside the cylinder, prevent the impellers from contacting each other. The lobes are mounted on shafts supported by anti-friction bearings, Fig. 2.

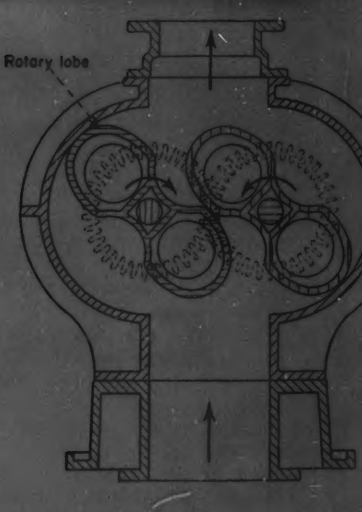
Rotary Liquid Piston—This design of compressors and vacuum pumps uses water or other liquids, usually in a single rotating element, to displace the air or gas being handled. The rotating impeller is mounted on a shaft and supported at each end by anti-friction bearings, Fig. 3.

Operating Range

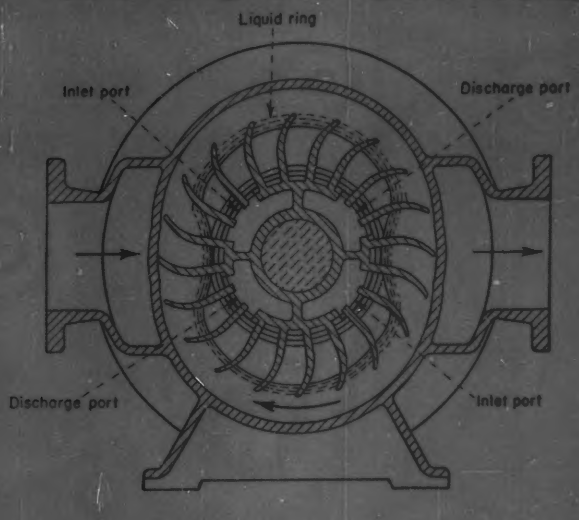
Rotary sliding vane units are available in standard sizes up to 6,000 cfm. and pressures up to 125 psig. Booster units are rated up to 400 psi. Speeds vary from 450 up to 3,600 rpm., dependent on unit size.

In general, single-stage rotary sliding-vane compressors are suitable for pressures up to 50 psig. and vacuums to 28-29 in. Hg referred to 30-in. barometer (standard reference throughout this discussion). The two-stage machines are designed for pressures up to 125 psig. and vacuums to 0.1 in. Hg abs. Three-stage compressors are good for pressures up to 250 psig. and booster units are available for pressures up to 400 psi.

Manufacturers' standard machines generally are sized to run at induction motor speeds. However, gas, diesel, gasoline or steam engine and steam turbine drives are readily adaptable. In many instances, V-belt drives are used



Mating lobed impellers compress large volumes. (Fig. 2)



Revolving liquid surges between rotor vanes to compress gas. (Fig. 3)

mounted directly on the compressor shaft.

Rotary-lobe compressors are available in sizes up to 50,000 cfm. and pressures up to 30 psig. Single-stage machines usually are good for pressures up to 15 psig. and vacuums to 22 in. Hg.

In some instances, introduction of various quantities of sealing fluid such as water has boosted vacuums several inches higher.

Two-stage compressors are designed for pressures up to 30 psig. and for vacuums of 25 in. Hg or somewhat higher.

Many of these units are driven by means of V-belt drives, reduction gears, direct-connected steam, gas or diesel engines and in some cases by moderate-speed direct-connected induction or synchronous motors.

Rotary liquid-piston units are available in sizes up to approximately 5,000 cfm. Standard single-stage units are used for pressures to 35 psig. and special single-stage units for pressures up to 75 psig. Units are staged above 75 psig.

Standard single-stage units will maintain vacuums up to 27 in. Hg. Standard two-stage units will maintain vacuums up to 29 in. Hg. Specially designed single-stage units will maintain vacuum to approximately 28 in. Hg.

Flow Characteristics

Flow of air or gas to and from the rotary sliding-vane compressor is constant and for all practical purposes non-pulsating. However, delicate instruments may show slight pressure variations.

In a sliding-vane unit, pressure is increased by reducing the size of the compression cell while it rotates from the suction to the discharge ports. As the unit rotates each compression cell reaches maximum size when it passes the inlet ports.

Further rotation of the cell reduces its size and compression is completed upon reaching the discharge ports.

Location of the discharge ports determines the pressure ratio at which the maximum efficiency will occur. Therefore, the port is located so that the peak efficiency will occur at the required pressure ratio of the unit.

Flow through the rotary lobe compressor is accomplished by the lobes, pushing the air or gas from the suction to the discharge. Essentially, no compression takes place within the unit but rather against system back pressure.

In the rotary liquid-piston type machine, flow of compressed air or gas is discharged in a uniform or non-pulsating stream.

Compression is obtained in this machine by rotating a round multi-blade rotor freely in an elliptical casing partially filled with liquid. The rotating force of the multi-blade rotor causes the liquid to follow the inside contour of the elliptical casing.

As the liquid recedes from the rotor blades at the inlet port, the space between buckets fills with air or gas. As the liquid reaches the narrow point of the elliptical casing, the air or gas is compressed and forced out through the discharge ports.

Regulation or Flow Control

All rotary compressors are classed as positive-displacement machines. In the application of any given unit it is normal procedure to apply a unit slightly larger in volume than required. The normal oversizing of a unit and the variance in process demand, requires the use of some method of control on most rotary compressors.

The rotary sliding-vane compressor can be controlled by one or a combination of methods.

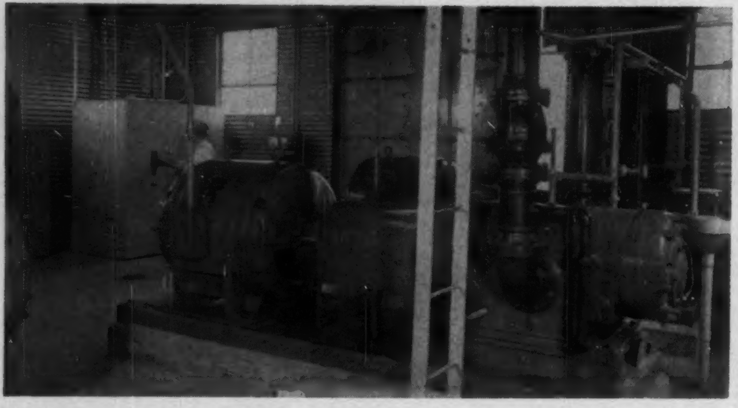
An automatic unloader control employs an inlet blankoff valve, a discharge relief valve and a pilot valve. To unload the compressor, the inlet is blanked off and the internal pressure is relieved to atmosphere.

In single-stage machines at maximum pressure, the power consumption when unloaded is approximately 25% of full-load power. In two-stage units operating at 100 psig., the power consumption when unloaded is approximately 15% of full load power.

Suction throttling can be used within certain limits established by individual manufacturers to reduce the weight flow through the compressor or compressors. Generally speaking, the power required will be reduced by suction throttling on units operating with pressure ratios above 3.0.

Bypass control is accomplished by bleeding partially compressed air or gas to the inlet or expanding some of the discharge air or gas in the intake cycle.

Another method of bypass con-



Sliding-vane units rated 1,065 cfm. at 50 psig. feed air to fuel gas. (Fig. 4)

trol is by the use of a pressure-operated automatic valve set to maintain the required discharge pressure. On gas units, the bypassed gas is routed through a cooler and back into the inlet or suction line.

Normal design of a sliding-vane unit is such that the speed may be reduced to approximately 50% of the rated rpm. For all practical purposes the volume and the horsepower will be reduced as the direct ratio of the speed.

When a rotary-lobe machine is driven by a constant-speed motor it delivers a constant volume which cannot be varied by restricting the inlet or discharge, without increasing the pressure. Excess capacity must be relieved manually or by a pressure-operated automatic bypass valve set to relieve at the required discharge pressure. On gas units the bypassed gas is routed through a cooler and back to suction line.

When the rotary lobe drive is a steam or gas engine, the desired suction or discharge pressure can be maintained by varying the speed within limits set by the manufacturer. In many cases units are not driven directly. Then, pulleys or sheaves can be changed to meet varying volume requirements.

Hydraulic couplings with constant-speed drives permit change in speed to vary volume. However, with this method there is no power saving nor any problem in cooling bypassed gas.

Application and Operation

Because of the wide range of possible pressure, vacuum and volume conditions, the rotary sliding-vane machine has perhaps the most universal application of the rotary machines. However, it too has certain restrictions and limitations that may be covered by other types.

According to available published information, the efficiency of rotary sliding-vane compressors above 10 psig. and 14 in. Hg vacuum referred to a 30-in. Hg barometer exceeds the efficiency of the rotary lobe and liquid-piston machines.

Except in a few instances, the speeds of a sliding-vane unit are higher and more adaptable for connecting directly to electric motors and in some instances internal combustion engines. This generally means a smaller unit for a job.

A water jacket is required to remove the internal heat of combustion, except for small units and those with low pressure ratios. Use of internal lubrication causes contamination of the discharge gases from compressors. However, after the gas is cooled most of the entrained oil can be removed.

It is necessary to remove dust, dirt, grit and other foreign materials from the inlet gas stream.

If gas to be handled is sufficiently corrosive to attack cast iron and steel then construction of the machine must be modified to include materials more resistant to corrosion. Also, corrosive substances may cause a lubrication problem.

On a rotary lobe compressor there is no contact between moving parts so that no internal lubrication is needed. For pressures less than 10 psig. and vacuum under 14 in. Hg, this unit usually is more efficient than other rotaries.

Cylinder is not water jacketed but at high vacuums and pressures an internal sealing fluid is used.

The same type of construction-material problems exist for this machine on corrosive service as were noted for sliding-vane machines above. However, there would be no lubrication problem.

With the rotary liquid-piston machine no internal lubrication is needed but a constant supply of sealing liquid must be furnished. Through proper selection of the sealing liquid, various corrosive gases and solvents can be handled by the unit without contamination of the gas or harm to the compressor. Liquid entering the unit, even in the form of slugs, can do no harm.

A comparison of available published information indicates lower efficiencies for this type unit compared to the rotary sliding-vane and the rotary-lobe compressors.

High Vacuum Producers

NOTE—Our symposium is incomplete to the extent that it does not include articles on diffusion pumps and mechanical high-vacuum pumps; we hope to fill in this gap within the next few months. For the record we mention these vacuum producers here.

Numerous processes operate at sub-atmospheric pressures. Once you get below a pressure of roughly ½ in. Hg, you are out of the range of rotary and reciprocating vacuum pumps of usual types, and into the range of multi-stage steam ejectors, oil-sealed rotary vacuum pumps, and diffusion pumps. Steam ejectors with up to six stages are good down to about 0.01 mm. Hg, and single-stage oil ejectors (sometimes used as boosters between diffusion and mechanical pumps) work down to about 0.001 mm. Hg. The oil-sealed rotary pump will pull down to about 0.0001 mm. Hg against a dead end, but has a practical pumping speed at pressures no lower than about 0.001 mm. Hg. For pressures below this, usual practice is to create the desired low pressure with a diffusion pump, which is good for back pressures as low as 0.0000001 mm. Hg, exhausting from the diffusion pump to a mechanical oil-sealed rotary at about 0.01 mm. The mechanical fore-pump then compresses to atmospheric.—*Editors.*

Drivers for Heavy-Duty Compressors (Fig. 1)

Driver	Horsepower Range	Avail. Speed, Rpm. (60 cycle power)	Speed Control	Efficiency	Starting Torque & Amperage, % of Full Load	Stalling Torque
Synchronous motor	100 to 20,000	3,600/N* (N = 2 through 20)	Constant speed	90 to 97% (1.0 or 0.8 leading power factor)	30 to 40% torque under 514 rpm., 85 to 125% torque above 514 rpm., 300 to 400% amp.	150%
Induction motor	1 to 5,000	3,600/N less 2% (N = 1 through 8)	Constant speed	10 hp.—86% 100 hp.—91% 1,000 hp.—94%	100 to 150% torque, 400 to 800% amp.	150 to 200%
Wound rotor induction motor	To 1,500 hp. @ 3,550; 1,750; 1,150; 870; 700; and 580 rpm. 1,500 to 2,500 hp. @ 1,750; 1,150; and 870 rpm.		100% down to 60%	10 hp.—86% 100 hp.—91% 1,000 hp.—94%	The speed-torque-amp. characteristics vary widely with the amount of external resistance.	
Steam engine	10 to 4,000	400 to 140	100% down to 25%	60 to 80% adiabatic expansion efficiency	About 120%	About 115%
Steam turbine	10 to 20,000	2,000 to 15,000	100% down to 25%	50 to 76% adiabatic expansion efficiency	Above 100%	About 115%
Integral gas engine	From 85 hp. at 600 rpm. to 3,300 hp. @ 300 rpm.		100% down to 60%	29 to 36.5% over-all thermal efficiency	Nil, started by compressed air	About 120%
Integral oil engine	From 100 hp. @ 600 rpm. to 1,100 hp. @ 330 rpm.		100% down to 60%	32% (HHV)	Nil, started by compressed air	About 120%
Coupled gas or oil engine	100 hp. @ 600 rpm. to 5,000 hp. @ 330 rpm.		100% down to 60%, except as limited by criticals	41% on gas (LHV), 36.6% on oil (HHV)	Nil, started by compressed air	About 120%
Combustion gas turbine	3,000 hp. @ 10,000 rpm. to 20,000 hp. @ 3,000 rpm. (1,000 ft. elevation, 80 F.)		100 to 50%	15 to 19% over-all thermal efficiency for simple open cycle, 22 to 24% with regenerator	Both single- and two-shaft gas turbines require sizeable starting motor or steam turbine. The single shaft requires much larger starting driver because of its poor part load torque characteristic. Two-shaft turbine has good torque characteristic.	

Note: Tabulation is limited to the commercially applied ranges of horsepower and speed. *N = Number of pairs of poles.

Drivers, Controls and Accessories

How wisely you select driver and controls for your compressor installation has a major bearing on how well it performs. Here are factors to orient your thinking, from the experience backlog of the contracting engineer.

Richard Hancock

While the compressor is the primary unit in any compressing station, drivers, controls and accessories must be selected with care for optimum, trouble-free performance. Some of the factors important to a good installation are covered in the following discussion of drivers, capacity regulation, seals, coolers, cooling water, pulsation bottles and separators.

DRIVERS

Half of any compressor installation is represented by the driver. Therefore, let us examine the advantages and limitations of various types of drivers commonly used with heavy-duty compressors. Basic characteristics are compared in Fig. 1.

Electric Motors

Squirrel-Cage Induction Motors—This motor is a fixed-speed machine. It is simple, rugged and reliable; has no rotating windings, slip rings, commutators, etc., associated with other types of electric motors.

For the majority of centrifugal compressors the high speed required is reached through a speed-increasing gear driven by a 1,200 or 1,800 rpm. squirrel-cage motor. Occasionally, design speed for a large-volume centrifugal permits

direct coupling to a 3,600 rpm. induction motor using 60 cycle power.

Reciprocating compressors frequently are driven through a speed-reducing V-belt drive or gear reducer by a 1,200 or 1,800 rpm. induction motor. Induction motors, sufficiently slow in speed to directly match speed of reciprocating compressors, are very expensive.

However, some of the newer, small reciprocating machines which operate at higher speeds such as 600, 514, 450 or 400 rpm. can be direct coupled economically.

Above 500 hp. very few induction motors are used to drive reciprocating compressors, either through reduction gearing or direct couplings.

While the squirrel-cage induction motor has very good starting torque, inrush current is very high on startup. If the electrical system cannot carry the high inrush current, it may be possible to use a low-voltage starter, provided the rotating inertia load can be accelerated with the reduced torque. At any rate, the compressor must be unloaded during the startup period.

The induction motor will carry a momentary overload of 50 to 100% without stalling, but it should never be selected for continuous overload operation.

Wound-Rotor Induction Motor—This variable-speed version of the induction motor has a rotor winding connected to an external variable rheostat through rotating slip rings. Because it can provide high starting torque with low inrush current, it sometimes is used to drive centrifugal compressors.

Despite the capability of the wound rotor to adjust speed from about 60 to 100%, its attractiveness is reduced greatly because over the entire range total kilowatt input to the motor and rheostat remains practically constant. As speed drops, part of the kilowatt consumption merely shifts from the motor to the rheostat.

Synchronous Motor—The synchronous motor is a fixed-speed machine. Some consider it less reliable than the squirrel-cage induction motor because it has a wound rotor to which d.c. excitation must be applied through rotating slip rings. Consequently, a small d.c. supply (M-G set or selenium rectifier) together with more elaborate starting equipment is required.

This disadvantage is offset considerably by the large air gap permissible on the synchronous motor, i.e., approximately $\frac{1}{8}$ in. compared with 0.040 in. on an induction motor. The importance of this difference is accentuated on large machines where it is difficult to center the rotor to close tolerances.

Not only is the air gap smaller on an induction motor but if the rotor is centered poorly it undergoes much greater pull from unbalanced radial magnetic forces. What happens in such cases is illustrated by two troublesome incidents with induction motors that we encountered recently.

The machines in question were standard 100 psi. plant air compressors built by two of the leading manufacturers in the field. In each case, the motor rotor was mounted on an extension of the compressor shaft. And the extended shaft had no outboard bearing.

Flexing of the extended shaft under the forces acting on it caused the rotor to rub the stator with resultant damage. The difficulty never would have occurred with the larger air gap of a synchronous motor.

Synchronous motors are classified commercially as "low speed" for 450 rpm. and lower, and "high speed" for 514 rpm. and higher. The starting torque for the low-speed group is 30-40%; for the high-speed group it is 85-125%. Because the synchronous motor is started as an induction motor the inrush current is high.

The synchronous motor frequently is selected for its high or leading power factor.

Like the induction motor it will take a momentary overload of 50% without stalling, but it should never be overloaded continuously.

Steam Drivers

Engines — Reciprocating steam engine cylinders are mounted integrally on the compressor frame and drive the compressor pistons through a common crankshaft. This driver is very reliable. It offers manual or automatic speed control over a wide range with sustained high efficiency at part load.

For some processes, however, the steam engine is ruled out today because it introduces cylinder lube oil into the exhaust steam. The oil increases fouling factor allowance on process exchangers. And on high pressure, high temperature boilers it can cause coke blisters on tubes if left in condensate.

Where oil in steam cannot be tolerated, the engineer must turn to the less efficient, less flexible turbine-gear driver.

Turbines—For centrifugal compressors the turbine is the most frequently selected driver and is connected directly to the compressor, Fig. 3. Turbines may be adapted reliably to automatic speed control.

The dependability of the steam turbine depends greatly on the design, installation and care of its control, lubrication and gland sealing system. Then it can be relied on for uninterrupted runs of 12 to 24 months duration.

When used for reciprocating compressors, the steam turbine requires a speed-reducing gear set. The pulsating torque characteristic of the compressor limits safe turndown of speed to about 10%. At a greater turndown there is the probability of encountering destructive torsional criticals because the speeds are appreciably lower than those for which the flywheel and couplings were selected.

Internal Combustion Engines

For Centrifugal Compressors—Only recently on pipeline installations have gas engines been applied to driving centrifugal compressors. One 3,750-hp. unit has been operating several months and others are on order.

Coupled to the compressor through a double-increaser gear set, the gas engine does offer the best fuel economy of any centrifugal drive available today. In some cases, speed variation may be limited by torsional criticals.

For Reciprocating Compressors—Four leading compressor manufacturers offer an extensive line of integral-frame, angle-type engine compressors. Burning either gas or oil, these machines have vertical power cylinders that drive horizontal compressor cylinders through a common crankshaft.

This compressor is the workhorse of the natural gas transmission field. It is used extensively in refineries where its fuel supply is a variety of waste gases. Many operating companies find the gas-engine compressor a natural choice

for petrochemical plants using a natural gas feed.

The combustion engine requires more maintenance than motor, turbine or steam engine. However, as a complete heat-cycle engine it measures up well against an all-steam or steam-electric cycle because of its excellent fuel economy.

Pipeline engine-compressor stations realize 98% availability of these units year after year. Petrochemical manufacturers begin to reach 95-98% availability during the second and third year of operation as operators and maintenance men get to know the machines.

During the last two years, compressor manufacturers have increased the horsepower ratings and over-all thermal efficiencies of engine compressors by supercharging. This gives the user more horsepower per pound of fuel and per cubic foot of foundation and building. Also, much less cooling water is needed.

The largest integral-frame engine compressor offered today is 3,300 hp.

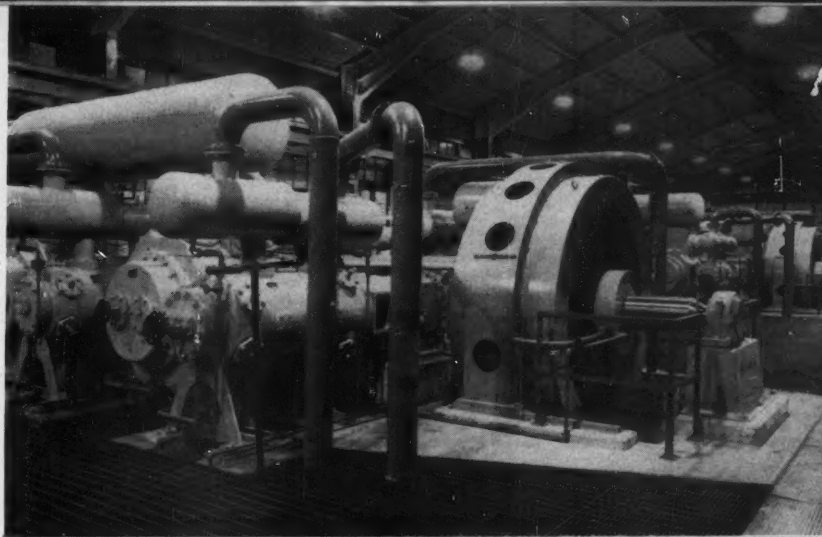
Coupled Engines—By coupling a separate engine to a balanced-opposed multi-crank compressor, the horsepower ceiling for a single unit can be lifted to 5,000 hp.

The coupled-engine arrangement also allows the manufacturer to adapt certain engine types not available in the integral-frame engine compressor. For example, Fig. 4 shows a 9,000-hp. installation of dual-fuel engines coupled to compressors.

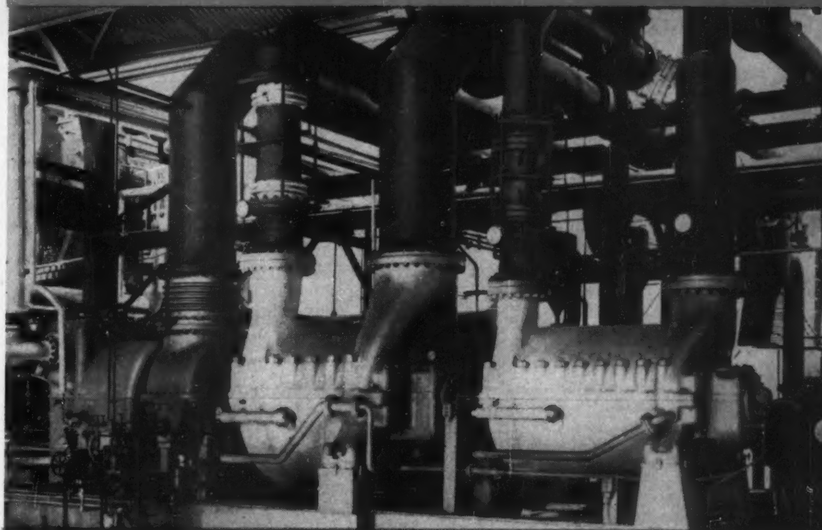
With a coupled dual-fuel installation an operator can take advantage of a lower price contract from an interruptable natural gas supply. When his supply is cut off during the cold weather, the engine will switch to oil automatically without shutting down. Also, he can bargain with competing fuel sources.

There is great interest in burning residual fuel oils in engine compressors. Apparently, there are few, if any, installations. Any engineer considering residual fuels would do well to reach agreement with the engine manufacturer on a specification for the fuel and the fuel-oil-treating facilities. Also, he should ask the manufacturer to produce maintenance records for similar engines on low-grade fuel.

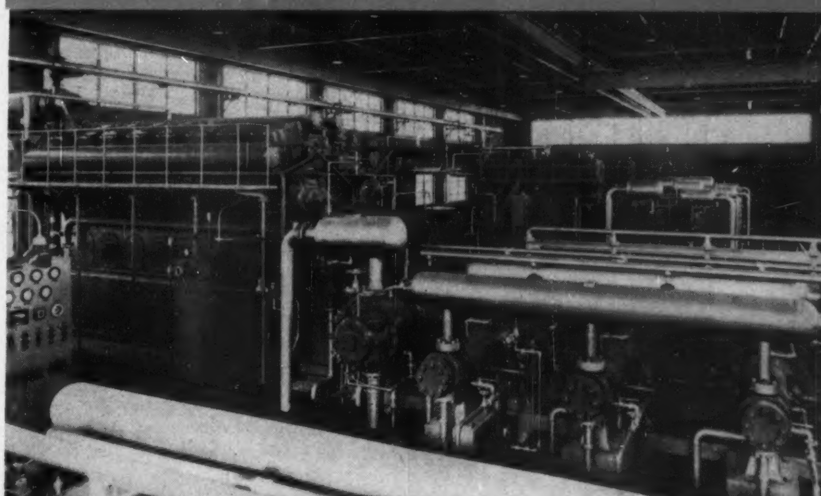
Gas Turbines—The open-cycle combustion-gas turbine is establishing itself rapidly as a prime



Synchronous G. E. motors drive Ingersoll-Rand compressors at Grace. (Fig. 2)

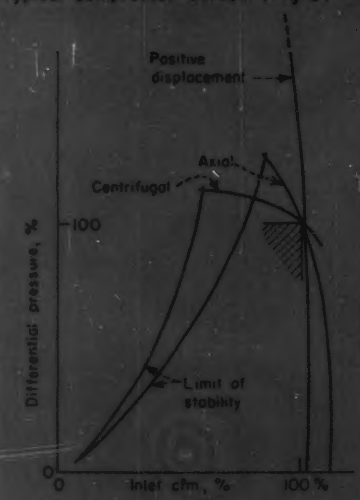


Westinghouse turbine drives Clark centrifugals at Spencer Chemical. (Fig. 3)

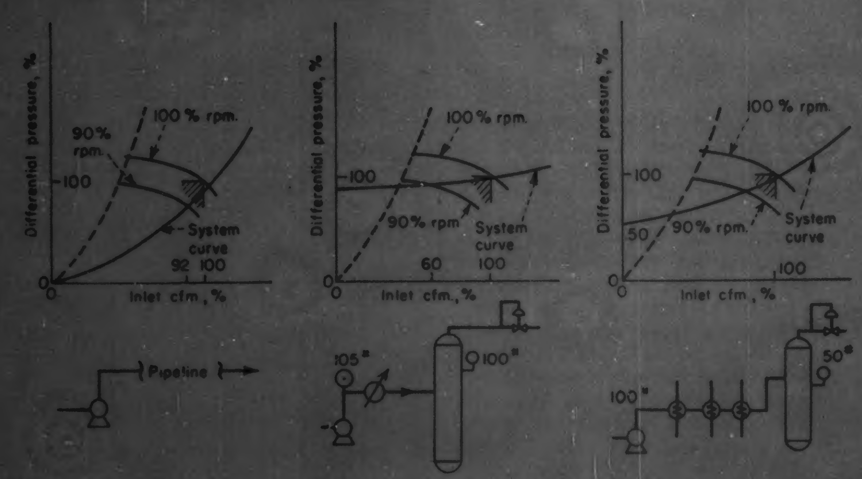


Cooper-Bessemer coupled engine-compressor at Coop Farm Chemicals. (Fig. 4)

Typical Compressor Curves (Fig 5)



Three Flow Systems Affect Same Centrifugal Compressor Differently. (Fig. 6)



Pipeline – system resistance curve is due entirely to friction. When speed is cut 10%, flow decreases 8%.

Constant-pressure vessel – system resistance curve is almost flat. Speed cutback of 10% drops flow 40%.

Combined system – resistance curve is summation of pressure and friction heads. Speed drops 10%, flow 15%.

For fixed-speed compressors the lower curves would be developed by suction throttling.

mover. Operating on gas fuel it is about as reliable as a steam turbine, will make long continuous runs without shutdown for inspection or maintenance. When using distillate or treated residual fuel the tips of the burner nozzles must be cleaned periodically and combustor liners replaced less frequently.

Basically, the open-cycle gas turbine is a very simple machine consisting of compressor, combustor and turbine. However, because of high temperatures, high speeds and close tolerances it must have complex apparatus for control, cooling, lubrication and emergency protection. Also, it must have a sizeable starting motor or turbine with disengaging clutch.

This prime mover has a comparatively inefficient heat cycle, unless the enormous quantity of heat in the flue gas is recovered. The two predominant recovery schemes are steam generation and preheating air to combustor.

Generally, the high speed of the combustion-gas turbine enables it to be coupled directly to a centrifugal compressor. Otherwise, a moderate-ratio gear speed-changer is used.

It is difficult to visualize a reciprocating compressor, driven by a gas turbine through a double-reduction gear reducer, that could compete with the integral-frame reciprocating gas-engine compressor.

Process Expander Turbines—Several high-pressure processes depend on recovery of the power in otherwise waste pressure energy to hold down utility costs so that the process can be economically feasible. Turbines used for recovering this energy may be standard impulse steam turbines adapted to the particular temperature and metallurgy requirements. Or they may be specially designed high-efficiency radial-inlet expanders operating in the 10,000-30,000 rpm. range.

Because these machines operate at high speeds they frequently are loaded with centrifugal compressors.

REGULATION OF CAPACITY

In order that you may select, apply and operate process compressors properly you should know the several methods for regulating the weight flow rate.

The best way to analyze regulation of any pump or compressor is to plot its Pressure vs. Volume characteristic against the System Resistance curve of the flow circuit. The machine will operate where the two curves cross.

Definition of Regulation Terms

Scfm.—Standard cu. ft. per min., referred to 14.7 psia. at 60 F.

Icfm.—Inlet cu. ft. per min., referred to the actual pressure and temperature conditions existing at the compressor suction.

Vol. Eff.—Icfm./Displacement cfm.

Bhp.—Brake hp. measured at the shaft.

Ihp.—Indicated hp. measured on the PV indicator card.

With this method we can size up any control problem by showing graphically how changes in either the flow circuit or compressor operating conditions will shift the operating point.

Pressure-Volume characteristics are shown in Fig. 5 for positive displacement, axial and centrifugal compressors. Fig. 6 illustrates how the same centrifugal compressor will respond differently to each of three different flow systems.

In our discussion of capacity regulation each scheme will be viewed from the standpoint of (a) capacity turndown from 100% of flowrate and (b) adaptability for automatic instrument control.

Unless otherwise stated, the following conditions are considered constant: gas composition, suction pressure and temperature, discharge pressure, and compressor speed.

Positive-Displacement Compressors

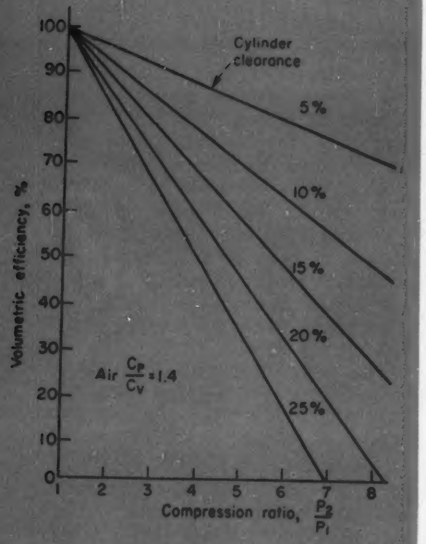
Speed Control—The positive displacement compressor produces essentially constant volume against whatever differential pressure is imposed on the machine, within limits of its mechanical strength.

The displacement, by definition, is proportional to rotational speed or strokes per minute. Accordingly, it may be shown that for changes in speed:

• Volumetric, mechanical and compression efficiencies are all essentially constant. (Mechanical and compression efficiencies correct for

Cooper-Bessemer coupled engine-compressor at Coop Farm Chemicals. (Fig. 4)

Volumetric Efficiency for Reciprocators. (Fig. 7)



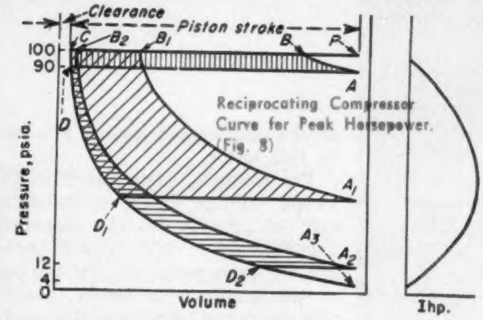


Fig. 8 uses Pressure-Volume diagrams to illustrate how a compressor cylinder starting with zero differential pressure will build up to peak horsepower at a compression ratio of about 3.0. If the suction pressure is further lowered the cylinder Ihp. will begin to fall and eventually reach zero. This occurs when the clearance volume gas requires the full stroke to reach suction pressure.

In each of the *PV* diagrams shown the lines *AB* represent compression, *BC* the delivery of gas at discharge pressure, *CD* the re-expansion of the clearance volume gas and *DA* the induction of a new charge at suction pressure. The Ihp. is proportional to *ABCD*.

When suction pressure equals discharge pressure the *PV* card is represented by the line *CP* and the Ihp. is zero.

By dropping suction pressure to 90 psia, we now have the thin *PV* card *ABCD* and the cylinder is taking a small amount of horsepower. The *PV* card gets fatter as suction pressure is continually lowered until it reaches a maximum, i.e. "peak horsepower" at 30 psia. inlet.

When suction pressure reaches 12 psia. the *PV* card has thinned out because the piston moves all the way from *C* to D_3 before the suction valves open—consequently very little fresh charge is inducted.

Finally at about 4 psia. the cylinder *PV* indicator rides back and forth on the adiabatic compression — expansion line A_3 *C*; Ihp. is zero.

rubbing friction, leakage through valves, piston ring blowby, etc.)

• Icfm. and Scfm. are proportional to speed.

• Brake horsepower is proportional to speed.

• Bhp./Scfm. and discharge temperature are essentially constant.

With such relationships, you can have efficient control by regulating speed. Capacity can be reduced by 50-75% either manually or automatically, depending on the method of lubrication and the type of driver.

Of course, each type of positive-displacement design has its own turndown limit. Some reciprocating machines, for instance, require special frame lubrication provisions below 50% speed. In a vane rotary, the blades do not seal well below 60% speed.

Similarly, lobe type rotaries have excessive slip below about 40% design speed. Turndown of the fluid piston rotary is quite limited, although there is some flexibility in each design.

Speed of compressor drivers such as steam engines, internal combustion engines, steam turbines, combustion-gas turbines and the wound-rotor induction motor can be controlled manually or automatically through instruments.

Suction Throttling Control—If suction gas is throttled manually or automatically to a lower compressor inlet pressure other variables change as follows:

• Compression ratio increases.

• Volumetric efficiency falls and Icfm. decreases, Fig. 7.

• Density of inlet flow drops in direct proportion with the changed inlet pressure (absolute).

• The Scfm. falls because of both decreased Icfm. and decreased gas density.

• Discharge temperature rises.

• The ratio Bhp./Scfm. increases.

• If original pressure ratio was less than approximately 3.0 the Bhp./Icfm. will increase; if greater it will decrease. See Fig. 8 with explanation of "peak" horsepower.

While suction throttling control can be used for turndown to zero, usually it is limited to a higher value because of piston or rotor overload (piston load increases even though Bhp. may be decreasing), excessive discharge temperature, Bhp. overload (see Fig. 8).

An automatic throttling valve frequently is applied to the suction side of the compressor to hold a controlled back-pressure on the process equipment. Then the inlet pressure of a constant-speed machine actually floats up and down with variations in weight flow.

Recirculation Bypass Control—When less than full compressor output is needed, the excess flow can be recirculated from discharge back to suction through a manually or instrument-controlled bypass throttle valve, Fig. 10.

Normally, heat of compression must be removed from the recirculated gas. This can be avoided only if the pressure ratio is very low, the total amount bypassed is quite small, or the period of bypass unloading is short term as when unloading for startup. If the circuit has no pre-cooler or after-cooler, it needs a bypass cooler.

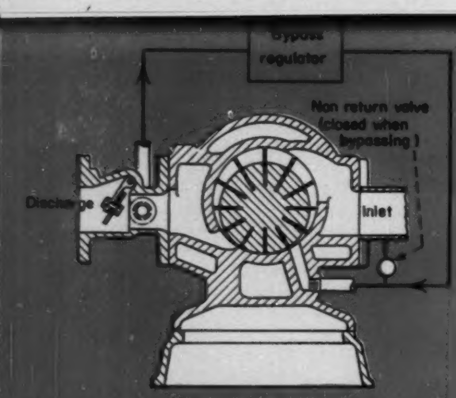
Bypass control can be used to turn down capacity from 100 to 0%. It saves no power at part load because the machine still is compressing 100% capacity up to full discharge pressure.

When the bypass valve is operated by instruments to control compressor output from 100% downward, the compressor cylinder(s) should be oversized several percent. Reason: even at 100% process load the bypass valve must be slightly open to hold a control point effectively.

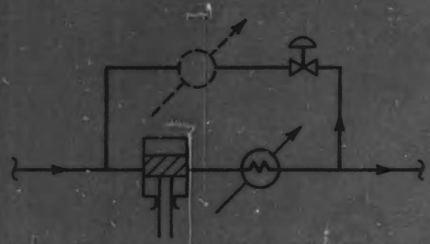
The vane-type rotary compressor can be equipped with a bypass control, Fig. 9. It is arranged so that part of the compressed gas is re-expanded against vanes to return energy to the rotor. This permits gradual instrument-controlled turndown to 50% capacity.

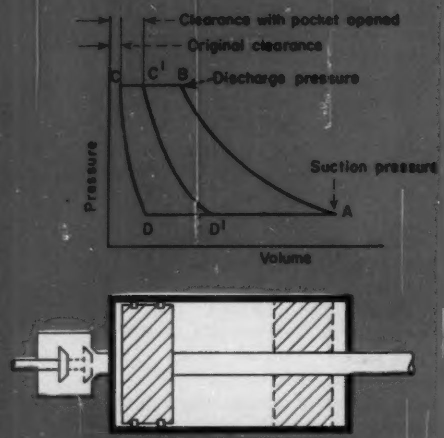
In contrast to bypass control; bypass unloading often is used to reduce power required for starting the compressor. However, in this case the total flow is recirculated through a line sized large enough to impose nil differential pressure.

Clearance Pocket Unloading—Inevitably, in any commercial positive displacement compressor there is a small amount of clearance volume within the compression chamber. During the delivery

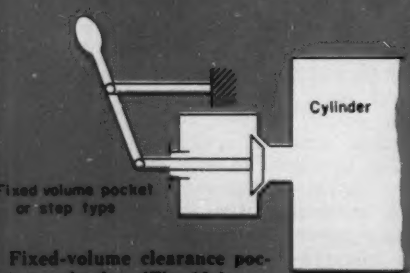


Bypass control, Fuller Co.'s rotary. (Fig. 9)

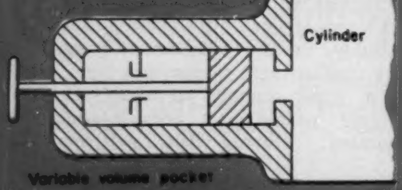

Recirculation control with coolers. (Fig. 10)



When clearance pocket is opened to unload reciprocator, PV card changes. (Fig. 11)



Fixed-volume clearance pocket unloader. (Fig. 12a)



Variable-volume clearance pocket unloader. (Fig. 12b)

stroke compressed gas is retained in this space.

For example, some 3-20% of the swept volume in a reciprocator cylinder actually provides clearance between piston and cylinder head and for valve ports, etc. At the end of the compression stroke, gas in this clearance space is at discharge pressure. On the suction stroke, it must expand down to suction pressure, Fig. 11, C to D, before fresh inlet gas can enter.

Meanwhile, the piston may have travelled 15% of its suction stroke. Hence volumetric efficiency will approximate 85%.

Now, if we arbitrarily triple this clearance volume by opening a clearance pocket at the end of the cylinder, holdup of compressed gas will be tripled at the end of the delivery stroke. Then, approximately 40% of the suction stroke, C' to D', Fig. 11, is required to expand this retained gas to suction pressure. Volumetric efficiency drops to about 60%.

Clearance pocket unloading is an efficient method for turndown control. Most of the temporary store of differential pressure energy in the clearance pocket is recovered as the gas expands against the piston on the suction stroke.

Clearance pocket unloader may be either the fixed-volume step type or the variable-volume piston type.

The step type, Fig. 12a, is a small chamber connected to one end of the cylinder through a valve which is opened fully to unload, and shut tight to load the cylinder. In the variable-volume type, Fig. 12b, a piston in the chamber is moved in and out of the chamber by a threaded stem to vary the clearance in vernier fashion.

Fixed-volume pockets are easily adapted to automatic instrument control. To date, very little has been done toward marketing an automatic instrument-controlled variable-volume pocket.

Large motor-driven, two-stage, 100-lb. plant air compressors generally employ fixed-volume clearance pockets to unload automatically in five steps, i.e., 100, 75, 50, 25, and 0%. Both the first and second stage cylinders must be equipped with four pockets each. Such complicated cylinder design is justified by the large power savings which can be realized on a varying demand load.

On the other hand, compressors on process service generally run steady at or near full load. Consequently, the designer allows only a minimum number of clearance pocket unloaders when he lays out patterns for the cylinder castings.

There is one very important limitation to keep in mind regarding clearance pocket unloading. It tends to become impractical at compression ratios below 1.8 because pockets are too large.

The rotary compressor unloader shown in Fig. 9 actually combines the features of clearance and bypass unloading.

Suction Valve Lifters—One end of a reciprocating-compressor cylinder may be unloaded by holding open mechanically one or more suction valves. This permits gas in the cylinder to escape back into the suction pipe during the compression stroke, with little power cost.

A single-acting cylinder will unload completely by this method in one step. The double-acting cylinder equipped with valve lifters at each end unloads in two steps, i.e., 50% at each end.

There is nothing gradual about unloading with valve lifters. Thus, it is better adapted to plant air compressors than to process units.

Valve lifters may be actuated manually, Fig. 13, or automatically. They unload the compressor simply, inexpensively and efficiently. Occasionally, application is limited because use would modify crank effort more than the crank and flywheel can accommodate. Or in other words, this technique cannot be applied to all cylinders everywhere.

Since rotary compressors are valveless they cannot utilize this unloading method.

Combined Unloaders—All the unloaders that we have discussed may be used together in various combinations for both manual- or instrument-controlled automatic sequential unloading. Valve lifters and clearance pockets frequently are combined to effect step control in 25% turndown increments per cylinder, particularly on plant air compressors.

Start & Stop Control—Plant air compressors driven by induction motors up to approximately 350 hp. may be provided with automatic start and stop control. A pressure switch on the air receiver starts the compressor when pressure falls

to a level such as 90 psig. and stops the unit when the receiver is charged up to 105 psig. Also required are a magnetic starter and automatically operated valve lifters to unload the compressor for a 10-sec. startup period.

A majority of these machines also are equipped with a selector switch to permit changing manually to constant-speed automatic valve-lifter or clearance-pocket unloading, as controlled by the receiver pressure pilot. This permits the operator to choose between automatic start and stop for periods of light demand or constant-speed control for the heavy demand part of the day.

Unloading at Startup—When a compressor goes on the line in a paralleled system already at operating pressure, it may be necessary to unload the machine during startup. Such is the case with electric motor and with combustion engine drivers. They do not have sufficient starting torque to overcome gas pressures while accelerating the rotating parts.

Positive displacement compressors may be unloaded for startup by any of the following methods:

- Open a liberally sized bypass circuit. One manufacturer suggests that the bypass line be sized to handle 10,000 ft. per min. velocity. Sometimes startup bypass unloaders are built into the cylinder.
- Open suction valve lifters.
- Vent discharge.
- Close the suction block-valve located right at the machine.

Centrifugal Compressors

The Head-Capacity Curve—First, let us review the Pressure vs. Cfm. characteristic of a centrifugal compressor and how it responds to changes at the inlet.

The Head-Capacity curve for a centrifugal compressor is quite like the characteristic curve for a centrifugal pump. In both cases, the curve is fixed for a given speed.

Both the centrifugal pump and the compressor will develop an increased differential pressure if the density of the inlet fluid is increased. For a centrifugal pump the pressure increase is directly proportional to the increase in density of the liquid.

Not so for the centrifugal compressor which may be examined by the unwieldy relationship:*

$$\frac{P_2}{P_1}=\left(\frac{\text{Adiabatic head}\times\text{mol. wt.}}{1544\times Z_1\times T_1\times k/(k-1)}+1\right)^{k/(k-1)}$$

where

P_1, P_2 = Inlet and discharge pressures, absolute
k = Ratio of specific heats, c_p/c_v
T_1 = Inlet temperature, absolute
Z_1 = Compressibility factor at inlet

Note that any one of the following changes, each of which increases density at the compressor inlet, will cause an increase in differential pressure:

- Increased inlet pressure, P_1
- Increased mol. wt.
- Decreased inlet temperature, T_1
- Decreased compressibility factor, Z_1

Also, note that a decrease in k value causes differential pressure to increase. Reason is not because of any density change at the compressor inlet but rather that the change in k value results in increased density of gas entering the diffuser and each succeeding impeller. The gas just doesn't heat up as rapidly during the compression process, that is, the process is in effect nearer isothermal.

How changing inlet conditions modify the compressor Head-Capacity curve is shown in Fig. 14.

Another difference between centrifugal pump and compressor curves is that the compressor is unstable below about 50% capacity. (See p. 209 for explanation.)

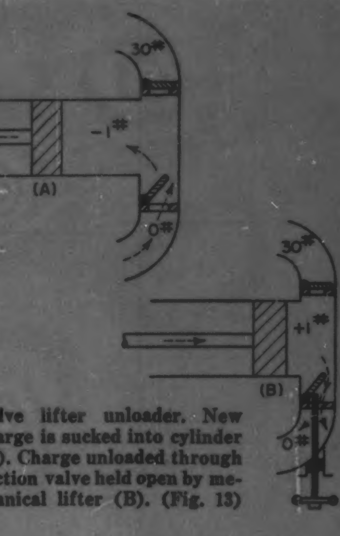
Speed Control—The centrifugal compressor Head-Capacity curve, like that for the centrifugal pump, retains its characteristic shape with speed change. And the rules that govern it are like those for the pump. For any fixed value of Q/N, i.e., Cfm./Rpm.:

- Capacity varies directly as the speed, $Q_1/Q_2 = N_1/N_2$
- Head varies as the square of the speed, $H_1/H_2 = (N_1/N_2)^2$
- Power will vary as the cube of speed, $Hp._1/Hp._2 = (N_1/N_2)^3$
- Efficiency will be nearly constant.

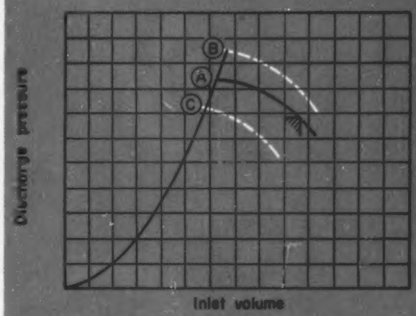
By applying these rules you can replot a given Head-Capacity curve for various speeds. See Fig. 15 and Fig. 6.

Only about 50% turndown of Icfm. is available from speed control because of the surge characteristic of the compressor.

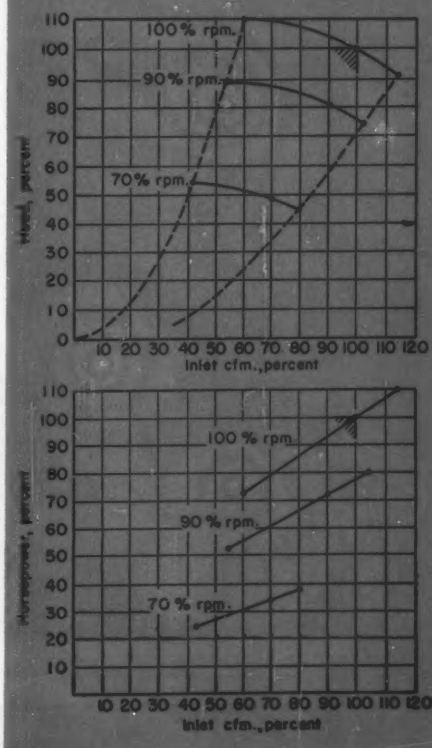
*This equation is not strictly correct. A more involved equation is required for precise treatment of the effect of deviation from the Perfect Gas Law.



Valve lifter unloader. New charge is sucked into cylinder (A). Charge unloaded through suction valve held open by mechanical lifter (B). (Fig. 13)

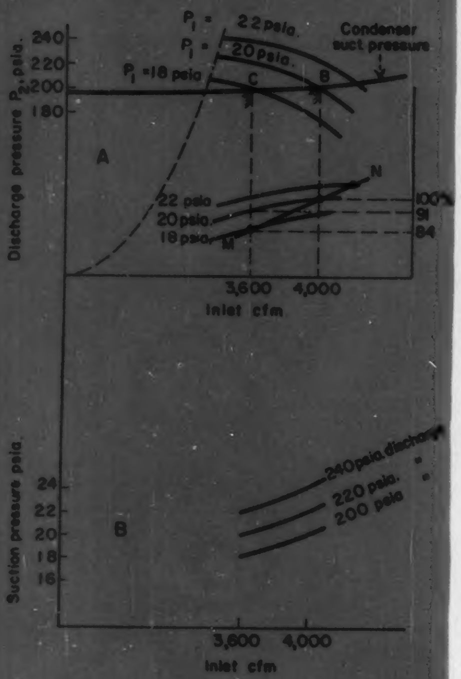


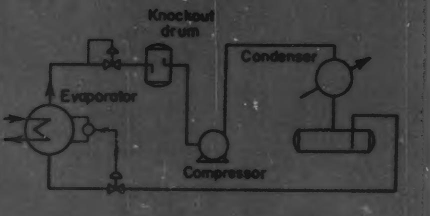
Change of inlet conditions modifies centrifugal head-capacity curve. (Fig. 14). Change from (A) to (B) results from: increased P_1 or mole wt.; decreased T_1, Z_1 or k. Reversal of these changes could produce (C).



Effect of speed change on centrifugal compressor. (Fig. 15)

pocket unloader. (Fig. 12b)





Suction throttling controls constant speed propane refrigeration compressor. (Fig. 16)

As far as the compressor is concerned speed turndown is efficient control. However, some drivers lose efficiency at reduced speed.

Evidence of the reliabilty of automatic speed control is found in records of uninterrupted one-year continuous runs. Such records are fairly common for centrifugal compressors driven by steam turbines and controlled by automatic flow or pressure instruments.

Suction Throttling—For compressors driven by constant-speed synchronous or induction motors, suction throttling in one form or another is the most efficient turndown control.

In Fig. 14 you see how the plot of differential pressure vs. Icfm. drops when the inlet gas is throttled to a lower pressure. In fact, the lower Pressure-Capacity curve shown in Fig. 6 could have been achieved with a constant-speed driver by throttling the intake from 20 to about 13 psia.

The propane refrigeration system shown in Fig. 16 is a good example of suction throttling control on a constant-speed compressor.

In such a system, when the condenser water is warm in the summer the compressor discharge pressure is held at approximately 200 psia. by the condenser. Temperature of the chiller is controlled by the back-pressure valve between the chiller and the compressor inlet. This holds chiller constant at 22 psia., and causes only a 2 psi. drop to the compressor.

Now, suppose the heat load on the chiller is reduced 19%. Weight of refrigerant evaporating per hour will fall off. The back-pressure valve will pinch down to hold a constant pressure in the chiller.

Action of the back-pressure valve also lowers suction pressure at the compressor from 20 to 18 psia. Result of these actions depicted in Fig. 16, is a shift from location *B* to *C* for the Pressure vs. Icfm. curve.

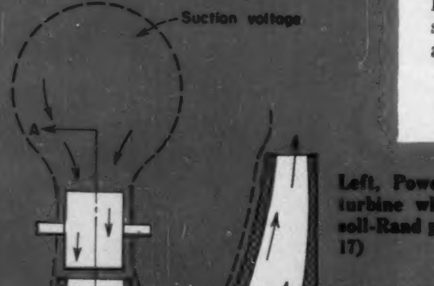
You will note that compressor flow has dropped from 4,000 to 3,600 Icfm. and the density of this flow has dropped in proportion to the ratio of suction pressures.

Net result of the action is that the back-pressure valve and compressor acting as a system took corrective action when load on the chiller decreased. The system levelled out at a weight flow rate of (3,600/4,000) (18/20) = 0.81 or 81% of the original flow. In spite of some energy loss through the throttling valve we have made considerable net power saving.

Look at the horsepower curves and you will notice that we actually are operating up and down the line *MN*. For a 19% turndown in weight flow, control by throttling suction would save about 16% Bhp. Discharge throttling would save about 9% and bypass control would save none. If control were by discharge throttling or recirculation bypass we would be operating on the 22 psia.-Bhp. curve *PN*.

In winter time colder condenser water reduces the compressor discharge pressure to a probable 180 psia. Then the compressor would operate against a lower system head curve and the suction throttling valve would take a greater drop to hold down the weight of refrigerant circulated.

Suction throttling control permits turndown to about 50 or 60% Icfm. before going into surge. If the normal suction pressure is



Left, Power recovery turbine wheel, Ingersoll-Rand patent. (Fig. 17)

Movable guide-vane inlet control. (Fig. 18)

compressor. (Fig. 15)

quite low, as in the above example, then the concurrent density reduction of the inlet flow increases the turndown appreciably.

Since discharge pressure is essentially constant, manufacturer should submit plot of suction pressure vs. Icfm. for three different discharge pressure levels. See Curve *B*, Fig. 16.

The curves in Fig. 16 are all plotted against Icfm. The next stage would be to plot them all against Scfm. referred to 14.7 psia. and 60 F., then convert to lb./hr. of refrigerant. Then we could see the effect of reduced inlet flow density at the lower pressures.

For compressor applications where suction pressure is less than approximately 20 psig. you must ensure that the shaft seal will function in the event suction pressure reaches vacuum.

Inlet Throttle Vanes—This is a special case where adjustable stationary guide vanes immediately ahead of the impeller eye throttle the suction, as shown in Fig. 18. All vanes are positioned identically by rack and pinion linkage.

The vanes convert most of the throttled pressure energy into velocity energy. It takes the form of an induced pre-rotation swirl which unloads the first impeller measurably and increases the stable range of the compressor.

Variable-inlet guide vanes can be applied to all stages of a multistage centrifugal but this is usually limited to the first impeller. This achieves the major aim of lowering the weight flow by reducing the density of inlet flow more efficiently than a throttle valve.

One manufacturer increases the efficiency of this control method by directing the throttled gas into a power recovery turbine wheel mounted on the compressor shaft. Gas enters at the periphery of the turbine wheel; the outlet forms the eye of the first compressor impeller, Fig. 17. Torque developed in the turbine wheel goes into the shaft, decreasing the driver load.

Like suction throttling, variable-inlet guide vanes are used almost exclusively for constant-speed motor-driven compressors. The method offers considerable power saving for part load operation when compared with recirculation or discharge throttling control.

Recirculation Bypass—The preceding discussion of bypass control for positive displacement compressors will hold for the centrifugal compressor with one exception: it cannot completely unload the power required, no matter how liberally sized the bypass. A centrifugal operating on a test stand with wide-open suction and discharge nozzles (no back pressure) will still absorb a large amount of power.

An automatically controlled bypass circuit, Fig. 19, frequently is applied to process gas compressors to keep the machine from going into surge. An orifice measures gross flow with the meter differential applied to an instrument-controlled valve in the bypass.

This control system is arranged to open automatically and bypass discharge gas back to suction any time the gross flow falls off near the surge limit of the machine. For example, if the limit of stability is known to be 60%, the bypass control will be set to prevent gross flow from falling below about 65%.

Without an automatic low-flow bypass a multi-stage centrifugal process-gas compressor might go into a surge unnoticed because of a process upset and begin immediately to heat up dangerously. When a multi-stage centrifugal is in surge, heat equivalent to perhaps 50% of rated Bhp. is being released into a small inventory of gas.

On a 2,000-hp. compressor over 2 million Btu. per hr. would be released within the compressor casing and adjacent piping.

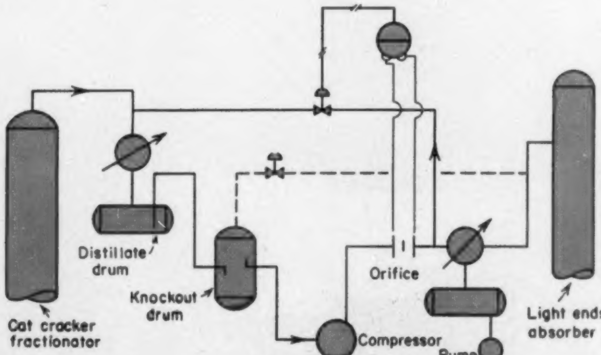
Should the gas be a mixture that includes some heavy fractions which condense in the after cooler, it is advisable to locate the recirculation take-off ahead of the aftercooler in order to sustain the molecular weight of the bypassed gas. Otherwise, the Pressure vs. Icfm. curve will become lowered during recirculation. Reason is that the molecular weight of the total gas flow to the suction will be depressed because it will be a blend of heavy feed gas and the lighter recirculated gas.

Discharge Throttling—As discussed and illustrated under "Pressure-Capacity Curves" a throttling valve located in the discharge line may be used to modify the System Resistance curve in order to vary the Cfm. operating point. This is simple, reliable turndown control that is inexpensive to install. But since there is almost no power saving, it is seldom applied to large horsepower machines.

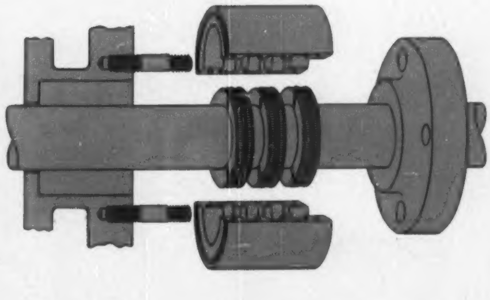
ACCESSORIES

Piston Rod and Shaft Seals

Most reciprocating, rotary and centrifugal compressors require a seal where the driving piston rod or shaft enters the compressor.

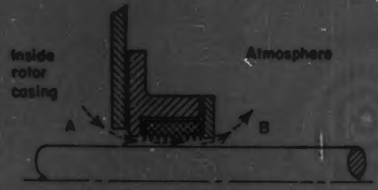


Automatic bypass guards compressor against surge. (Fig. 19)

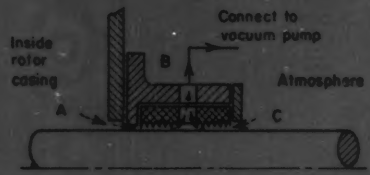


Springs hold sectional France packing. (Fig. 20)

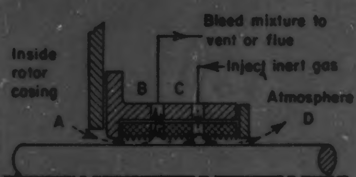
Movable guide-vane inlet control. (Fig. 18)



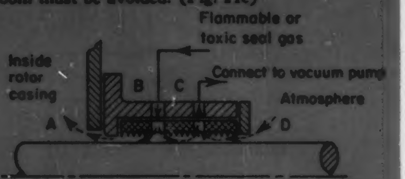
Single element for air or inert gas blowers is used where nominal out-leakage is permissible. On a vacuum compressor air flow would reverse. (Fig. 21a)



Vacuum at interlabyrinth draw-off point (B) prevents gas leakage to atmosphere. Where process gas cannot tolerate air, draw-off point (B) is used for injecting compatible buffer gas at pressure above casing pressure. This also keeps flammable, toxic or dirty gases from escaping to atmosphere. (Fig. 21b)



Labyrinth arrangement used where process gas cannot be contaminated by inert seal gas and leakage of process gas to compressor room must be avoided. (Fig. 21c)



If flammable or toxic seal gas must be used this scheme prevents leakage to the room. (Fig. 21d)

Two considerations are focusing attention on sealing today. One is the ever increasing variety of flammable or toxic gases being handled at ever increasing extremes of temperature and pressure. The other is the continual effort at improving techniques in order to extend the life of packings and minimize costly down-time.

Soft Packings — Graphite-impregnated asbestos packings, sometimes with metal-foil coverings, may be used to seal reciprocating piston rods for moderate pressure. The packings are lubricated and the stuffing box is usually water-jacketed for cooling. This same packing is used on lobe-type rotaries with grease lubricant.

Soft packings are rarely used on centrifugals because the high rubbing speeds generate more heat than can be removed unless an elaborate system is provided to flush the seal with liquid coolant.

Solid Packing Rings—Most process compressor piston rods and plungers are sealed with several rings of packing machined from a variety of metals and organic materials. They must have sufficient dimensional stability to withstand the forces, temperatures and rubbing. The material must accept a high polish.

Each ring is sectional and held by a garter spring (See Fig. 20). These packings are fed from a shot-feed lubricator except on the non-lubricated cylinder construction which employs dry carbon rings.

Except in cold applications packing boxes are water jacketed. For pressures above about 6,000 psig. packing rings are cooled very effectively by circulating oil or water in annular spaces between the packing case I.D. and the O.D. of rings.

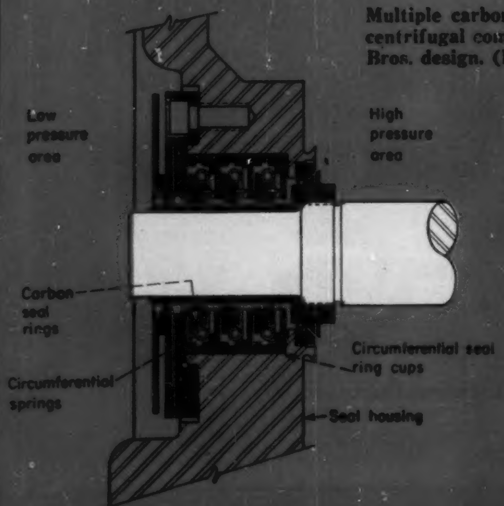
The important considerations for rod packings are:

- Selection of materials for rod and packings.
- Alignment, both cold and running.
- Cooling of packings.
- Finish of rod and packings.
- Cleanliness of gas and inlet piping.
- Careful break-in of new packing.

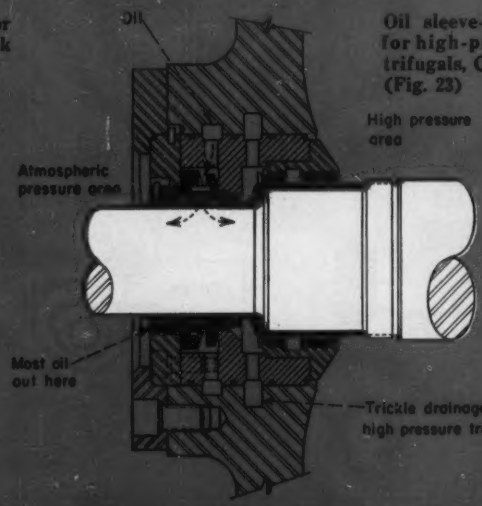
The gas leakage on properly designed and installed rod packings will be on the order of 1 to 3 scfm. They have been observed to be bottle tight for extended periods of operation.

Labyrinth Seals—A labyrinth packing consists of a succession of close-clearance knife edges which seal rotary shafts by throttling leakage gas. The amount of leakage gas may be from 1 to 4% of rated compressor capacity when the seals are new. This is the most widely applied packing on centrifugal compressors.

Labyrinth packings are very reliable because there are no rubbing parts nor any cooling or lubricating liquids required. They are made of soft materials with a good rubbing characteristic. Then when a rub occurs, the knife edge will roll over and open the clearance without tearing. They are limited in the amount of pressure that can be sealed because leakage becomes



Multiple carbon-ring seal for centrifugal compressor, Clark Bros. design. (Fig. 22)



Oil sleeve-bearing seal for high-pressure centrifugals, Clark design. (Fig. 23)

costly in terms of both horsepower and loss of product.

On steam turbines labyrinths seal pressures as high as 150 psi. using one bleed-off point. On compressors they are seldom used to seal pressures over 10 psig. on process gases. On air or on inert gas labyrinth seals might be used for considerably higher pressure.

Although the labyrinth is a very simple seal it becomes most versatile when the shaft span permits the use of several seal elements. See Fig. 21 illustrating how labyrinths may be applied to toxic or flammable gases.

Dry Carbon Ring—Self-aligning sectional carbon-ring seals with garter spring retainer, similar to packing illustrated in Fig. 22, are used extensively in sealing steam-turbine shafts. They are intended to operate with a clearance of a few thousandths between center and left.

On compressor shafts they are limited, however, because there is a tendency for carbon rubbing against metal to heat and wear rapidly in a bone-dry atmosphere. A single carbon ring is sometimes used in conjunction with labyrinth packings.

Lubricated Carbon Rings—The life, reliability and range of application of carbon-ring seals is greatly extended by flowing a stream of oil or other suitable liquid past the sealing faces to cool and lubricate the rubbing parts. Carbons which seal at the axial face, like those extensively used in centrifugal pumps, are also used on rotary and centrifugal compressors up to about 150 psig. stuffing-box pressure.

Oil Sleeve or Bearing Seal—This is a high-pressure seal developed about eight years ago for natural gas pipeline compressors. It consists of a self-aligning close-clearance sleeve assembly arranged for oil feed to a central groove, Fig. 23.

The oil is fed at sufficient pressure and quantity to ensure end-leakage oil flow in both directions, thereby preventing gas leakage along the shaft. Slinger disks and drains must be provided on both sides of the sleeve to collect oil.

The inner-leakage seal oil contacts the process gas. Consequently, for certain applications involving corrosive gas the contaminated or "sour" seal oil cannot be returned directly to the seal oil reservoir for re-use. Manufacturers have refined this sealing technique for sour gases so that only a few gallons per day of sour oil are drawn off via the inner seal drains.

This seal is in wide use today in the range of 500 to 1,000 psig. and will undoubtedly be extended to higher pressures.

Viscosity Pump Liquid Seals—This centrifugal compressor seal employs a shaft-mounted disk rotating in an annular chamber, See Fig. 24, which is kept filled with liquid. The viscosity pumping effect of the serrated disk generates a small amount of head to seal against a differential of a few psi.

The sealing liquid must be circulated for cooling. This seal has been used for years on coke oven and manufactured gas boosters.

Intercoolers and Aftercoolers

Intercoolers serve to remove the heat of compression between stages. The cooler used after the final stage is called an aftercooler. On air compressors or wet gas compressors each cooler must be followed by a moisture separator.

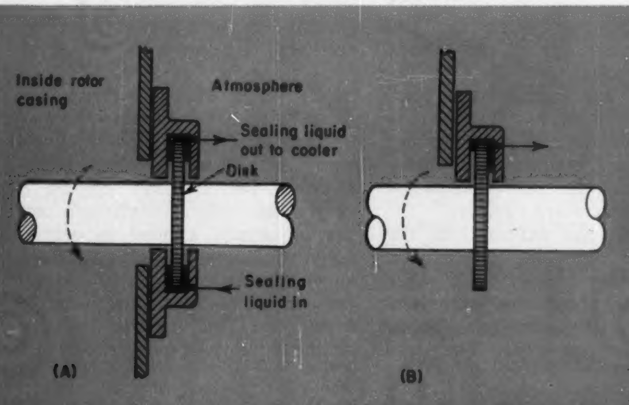
The heavier-duty plant-air compressor usually has a water-cooled intercooler of a functionalized design to fit neatly and compactly on to the machine. These machine-mounted air intercoolers are fitted with a moisture separator and trap to remove condensate.

Intercoolers and aftercoolers for process compressors are usually located outside the compressor building in a typical exchanger row. On horizontal electric-driven machines, however, it is often practical to use machine-mounted intercoolers, Fig. 25.

Separators

Two classifications of separators are installed ahead of compressors. One is the knockout drum which prevents slugs of liquid from entering the machine and bursting the cylinder or wrecking the rotor of a centrifugal.

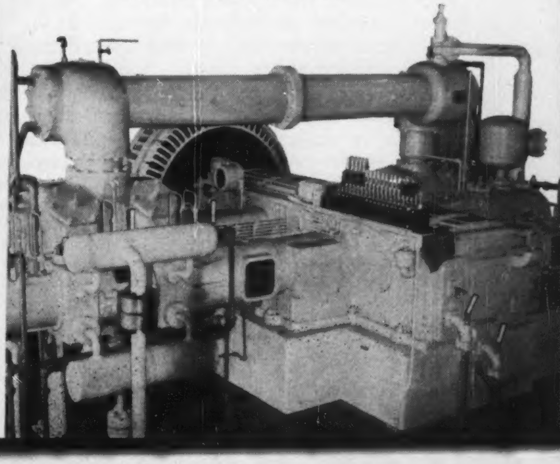
A more refined type of separator normally is installed after intercoolers on reciprocating compressors to eliminate droplets of lube oil or condensibles on valves. These droplets shorten valve life.

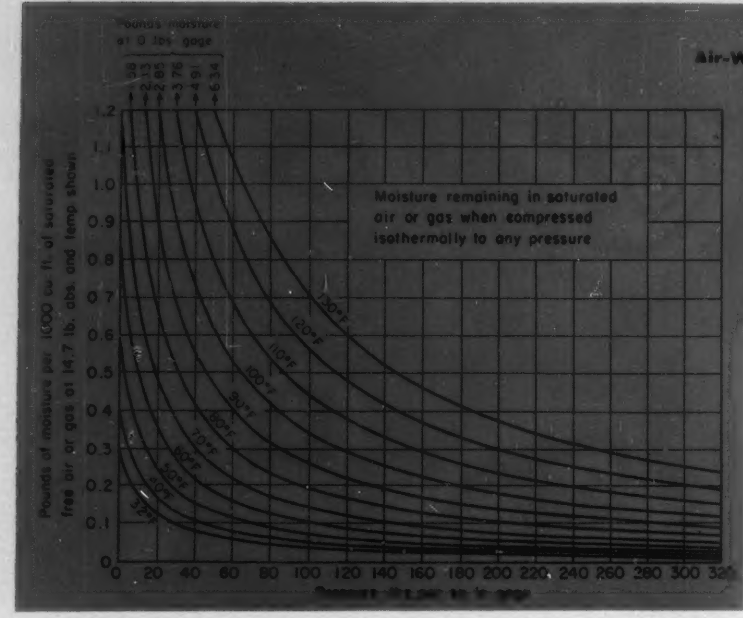


Liquid seal with no pressure in the casing rides evenly on each side of disk. (Fig. 24a)

Liquid seal under 5 psig. differential pressure is displaced, yet holds. (Fig. 24b)

Machine-mounted intercooler on reciprocating compressor that compresses ammonia synthesis gas. (Fig. 25)





Air-Water Saturation Curves. (Fig. 26)

Air saturated with moisture at intake conditions, 0 psig. and 80 F., contains 1.58 lb. of water vapor per 1,000 cu. ft. If compressed to 100 psig. and cooled back to inlet temperature it would contain only 0.19 lb. of moisture. Unless intercoolers or aftercoolers were used discharge from a 1,000 cfm. unit would drop out 10 gal./hr. of water in system.

Moisture separators of this type are available in a variety of designs which employ the impingement principle of separation, sometimes with woven or random wire mesh to coalesce the droplets. They also should be equipped with some storage capacity and a gage glass.

The chart in Fig. 26 shows amount of moisture to be expected from air compressor intercoolers.

Pulsation Dampeners

As reciprocating compressors have increased in capacity and speed it has become more economical to use pulsation dampeners or volume bottles instead of oversized lines.

Pulsation dampeners serve two purposes. They make it possible for the cylinder to perform as it was designed i.e., without permitting pressure wave nodes to starve or supercharge the cylinder during the suction stroke. This is why the manufacturer wants them.

They also serve to reduce piping vibrations which can result in fatigue or other mechanical failure. Dampeners are recommended particularly where cylinders operate in parallel.

The purchaser today is urged to follow one of two courses: either install "pulsation volume bottles" together with laterals and headers sized as recommended by the compressor manufacturer, or turn the problem over to a manufacturer who specializes in pulsation dampeners. There are two such concerns with considerable experience.

Cooling Water Systems

The engineer can no longer afford to be casual about the temperature and cleanliness of jacket cooling water if he wants long continuous runs and satisfactory life from his compressors. It has been shown that when the Old Timer rammed all of the coldest water he could get through the jackets of his engines and compressor cylinders he was actually causing sweating on the cylinder walls. The condensibles were cutting away the film of lubricant and the metal wore rapidly.

We know the safest rule for compressor cylinders is to feed cooling water which has been tempered to about the same temperature as the inlet gas (unless the gas is bone dry). Tempered water can usually be taken from the warm side of an oil cooler or intercooler. If tempered water is not provided the operator should throttle back until the water leaving the jackets is quite warm i.e., 120 to 150F., in which case water may be treated to avoid scaling.

For oil and gas engines the manufacturers recommend a recirculated soft water system designed to provide entering cooling water at 150 to 180F. If the water is dropped below 140F., cylinders wear fast.

There are an increasing number of successful installations of vapor phase or ebullition cooling on engine jackets. This is a closed system, which does not require a circulating pump but depends on boiling action in the jackets for forced circulation. This system can be modified to generate a considerable amount of 10 or 15 psig. steam for comfort or process heating.

Shell-and-tube lube-oil coolers can be made suitable for almost any cooling water. The compressor manufacturers generally use $\frac{1}{2}$ in. O.D. tubes.

There has been a revival of interest and application of diaphragm cooling on centrifugal compressors. It permits extending the head capability of a small single-casing multi-stage machine by some 10 to 15%. Because the cooling passages tend to be small and tortuous the manufacturers recommend a recirculation system of very clean water. Diaphragm cooling is usually applied to centrifugals which operate with discharge above approximately 450F., and if the cooling passages are permitted to clog or foul up the discharge temperature rises dangerously.

Modern Approach to Pilot-Plant Design

. . . A Philosophy

. . . Not a Formula

JOHN D. GROTHE, Dorr-Oliver, Inc.

All too often today, the question of pilot-plant design is looked upon as a matter of producing a miniature version of a projected commercial plant.

It is broadly assumed that it's merely necessary to reduce the scale. A reasonable period of operation will then iron out the weak spots in the preceding laboratory work and give an exact picture of events to be expected from the full scale plant.

Actually, the whole subject of the pilot plant requires an approach quite different from that usually taken toward the full scale commercial plant. In fact, it is necessary that the pilot plant be handled with exceptional skill and understanding if all hopes are to be realized.

This general statement is true for two situations. One, where the pilot plant is designed to prove out a specific flowsheet or process. The other is a permanent and flexible test plant, designed to operate under the varying conditions encountered in a diverse and steady flow of separate problems.

The latter, because of the need for extreme flexibility, if for no other reason, presents the more complex problems of design. While we are primarily concerned here with the philosophy of approach to the true pilot plant—designed to bridge the gap between the laboratory study and the full scale plant—there is something to be learned from a general look at the requirements of the test plant.

Test Plant Can Be Useful

Such test plants are rarely built with a definite, specific investigation in mind, but they may be called upon to work under a wide variety of circumstances. They are therefore laid out primarily with the view of providing flexibility.

Generally they are a storeroom of prototypes of industrial equipment, much of it mounted on dollies or casters. Rarely is equipment set up on permanent foundations or permanently connected together. Much may be idle a good deal of the time, and put into service only when required for a particular application. For this reason, this equipment will more often than not fail to fill the requirements completely, or balance with the other items of the flowsheet for the particular process under investigation. The test plant, made up largely in this manner, will almost always produce data subject to considerable extrapolation and interpolation.

In addition, in such a test plant, other problems may arise which are not inherent in the experiment itself; adequate supply of sample, difficulties with waste disposal, contamination of the atmosphere and proper water supply. Altitude, which may affect the process and climatic conditions are other factors that remain unknown.

This does not imply, of course, that this type of test plant doesn't fulfill a useful role. On the contrary, as a means of investigation it can be extremely valuable if you understand the limitations. It is the logical next step after bench-scale experiments and can answer many questions and save money before a pilot plant (in the sense we are discussing) is decided upon. The test plant, however, should not take the place of extensive and intelligent laboratory work, and should, no more than the pilot plant, ever replace the laboratory.

No Substitute for Lab

Properly conducted laboratory work has the objective of determining the main steps in the process to be developed or applied.

Equipment and methods of testing should simulate actual practice as closely as possible. But since laboratory work is generally carried out in batches, there is still a large factor of experience that must be applied to large plant practice. And even with long experience it is still unsafe to base estimates on tests involving a few grams of material stirred up in a beaker.

The laboratory program should, however, answer categorically the question "Will it work?", and should provide data to answer the question "Is there any chance that it will pay?" It should be the laboratory work that provides the information for calculating any risk involved.

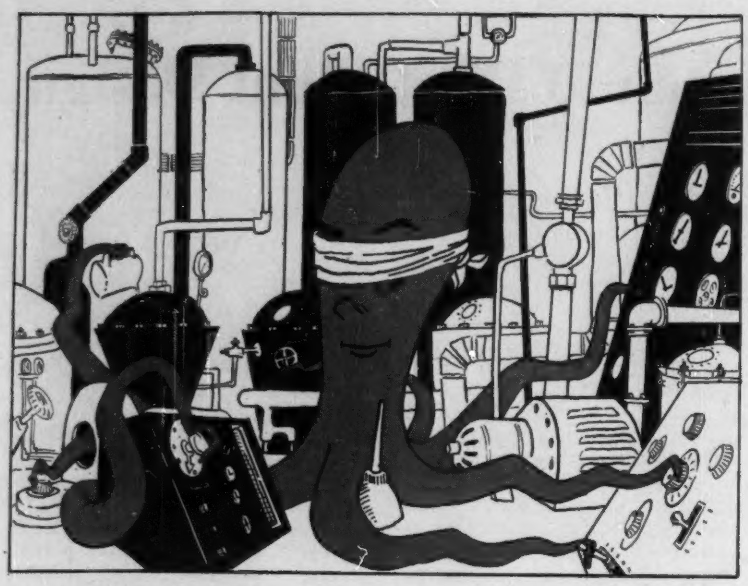
In addition, laboratory work should be carried far enough to answer most process questions; to outline a complete flowsheet; to consider such factors as materials of construction and probable effect of impurity buildup.

In other words, pilot-plant or test-plant construction should not be undertaken until all factors have been weighed and tested in the laboratory. The pilot plant should be a confirmation of the interpretation of laboratory tests just as the large plant will be the confirmation of pilot-plant tests.

Where, How Big?

Once the decision have been arrived at to build a pilot plant, a whole set of questions arise.

Location—With regard to location, shall the pilot plant be built close to the supply of raw material in order to reduce transportation costs, or should it be located at the probable site of the projected industrial plant? Will an adequate and competent operating staff be available at this site, and will co-operation with the other company



"Far too often, the research man abandons some of his brains at the door of the pilot plant. He understands it's the place to make errors . . ."

functions be assured better at some location nearer headquarters? These are questions that must be answered in accordance with the particular situations involved in a problem.

Scale-Up—Scale must be large enough to give meaning to the measurements being taken and if possible there should be some relation to the ultimate capacity of the commercial plant. It is, of course, important that the scale be such that the individual units of equipment themselves bear some relation to the size of these units in the commercial plant. The scale should never be so small that mechanical difficulties in the operation of the equipment will add problems out of proportion to those expected later on. An example of this might be the difficulty due to exaggeratedly small volumes flowing through pipes, or the trouble of keeping pumps primed. Often this difficulty is avoided by added circulation, which, however, may tend to obscure the true test conditions.

It will be necessary to decide, in choosing the scale, which of the unit steps need investigation, and which are already so well known that relatively small expenditures are needed to prove them out. Some dimensions can be reduced in direct proportions, others cannot, and therefore in choosing a scale for the pilot plant, these factors must be understood.

For example, in percolation leaching, capacity may be a straight volume function based on contact time between solvent and ore, but the relation between area and depth also plays an important part and should be understood and given due weight, both in the design and in the interpretation. Reactions taking place in columns often require not only time but hydrostatic pressure. Thickening, a relatively simple and well understood operation, is a typical example where scaling downward in even ratios will not work.

"How the plant will behave under extreme conditions must be evaluated. To neglect these extremes . . . means courting disagreeable surprises later on."

There are many such unit operations, the nature of which should be studied in advance of designing the pilot plant or even in advance of deciding the scale. In percolation again, the percolation rate is one important variable, but proper solvent distribution must be assured and channeling through the mass avoided. Channeling along the walls of the leaching vessel will be a different matter in a tall narrow tank from that in a tank of the same depth but with a much greater area. Distribution of solvent over a small area is not the same problem as distribution over a large one.

Many heat balance factors cannot be scaled directly since they are complicated by the volume-to-surface ratio problem.

An attempt should be made to consider the salvage of pilot-plant equipment. If the size of equipment is chosen properly, after successfully accomplishing the original purpose, much can be used in the large plant.

Don't Cut Corners

The scale chosen will obviously have a great effect on the first cost as well as on the operating cost of the plant.

Normally a pilot plant will not be decided upon until an approximation of cost at the projected commercial capacity has been made, and the risk factor, both technical and commercial, has been fully evaluated. It would seem to be questionable wisdom then, at this stage, to attempt to cut corners. By using equipment that happens to be immediately available, by building up the flowsheet from miscellaneous discarded or temporarily unused machinery, whether or not it really fits into the scheme, some money can be saved—but this is often false economy.

Difficulties that are bound to arise as a consequence will either falsely discredit the merits of the process or exaggerate its shortcomings. In any case, it will be necessary to interpret and to make allowances, and the purpose for which the money was originally spent will be missed. Such a course will also almost inevitably result in loss of time, and time is a most important and valuable element in any program.

A Big Problem—Samples

One of the most important factors that arises constantly—in laboratory process development as well as in connection with pilot-plant operation—is the matter of samples. Most engineers know that care should be taken to make sure the sample is properly representative of the raw materials. An average sample might be representative for purposes of raw material valuation. But from the point of view of planning, exploitation, and certainly from the point of view of designing a proper treatment plant, the feed will hardly ever be a representative average—and variations from the average, both up and down are important.

How the plant will behave under extreme cases must be evaluated. The extreme variations from the average may have been determined in advance. But to neglect these extremes in the testing program or in the pilot plant, under the misconception that the sample is a true average sample, means courting disagreeable surprises later on. For this reason alone, if for no other, flexibility in the pilot plant arrangement is a sine qua non. This requires careful thought in layout arrangement and choice of equipment.

". . . the man who will eventually carry the responsibility for the design of the ultimate plant should also play a major role in the design of the pilot plant."

Changes in the flowsheet may necessarily have to be made as the testing program advances. Therefore, it's important that layout of the pilot plant be such that these changes can be made at minimum cost and with a minimum loss of time.

It is desirable, from the point of view of loss of time, that the pilot plant have the smallest practicable inertia factor. Then changes in the method of treatment, in the amounts of reagents or the point of their addition, or other operating variables will be quickly reflected.

Excessive storage and dead volume should be avoided, but not to the extent that the effect of prolonging storage on the products will be obscured.

Nothing should be done that will hamper easy access to every piece of equipment. Everything should be avoided that will make cleaning and maintenance difficult. Space around machinery should be liberal, especially since space is not a large economic factor at this stage. A cramped layout will generally turn out to be expensive rather than cheap.

"Some money can be saved by using equipment that happens to be available, regardless of whether it fits into the scheme—but this is often false economy."

Some Are Illegitimate

Pilot plants are built for all sorts of reasons, most of them legitimate, but some are not.

Often a fancy "pilot plant" will be put together by the same sort of people who would salt a mine, when capital is to be charmed out of the pockets of the unwary. Nothing impresses the layman more than to be shown a pilot plant in operation when he can say that he saw the stuff coming out. It is very easy to produce impressive figures of recovery "obtained right here in the pilot plant, under industrial conditions," but for the same reason it is also extremely easy to fool oneself and to be sincerely misled.

It is different when it's necessary to convince a Board of Directors—who may be laymen—of the workability of a process before they will invest any sums in a new plant. If the conduct of the pilot plant work has been otherwise properly carried out from a technical point of view, it is nevertheless sometimes necessary to make this final demonstration which may well be the deciding factor. But, to build a pilot plant merely to raise project money reflects failure on the part of the responsible technical officials. *(Continued)*

Most Fill a Need

Many pilot plants, at least in the chemical industries, are built for an entirely different purpose. It is often necessary to test market acceptance of the product on a scale which would be difficult to satisfy by a laboratory, rather than to answer technical questions about the process.

Market-Testing—An example might be the case of a process which, it was claimed, would produce a battery manganese with valuable properties, especially regarding the life of the battery. The only way to demonstrate this claim conclusively was to make a fairly large number of dry batteries of various sizes and to submit them to actual use tests. The technical problems in actual production were comparatively simple, and the preparation of the electrolyte itself was pretty thoroughly understood. To have gone to the expense of a full fledged pilot plant in this case for technical reasons alone would obviously have been a waste of time and money. And yet, there was no other means of answering the main question except by manufacturing enough of the end product.

Sometimes people want to build a pilot plant to investigate a new process on which somebody else, due to patents, can collect a royalty. Generally, however, no royalty is due if the process is to be operated experimentally. An unwary patentee, dealing with an unscrupulous client, can find himself in the position of having waived his royalties. Although ostensibly granting rights for experimental purposes, his client has in effect built a "pilot plant" that for all intents and purposes is as large as any commercial plant, and continues to operate it as such. Sometimes the "pilot plant" may be operated with the sole purpose of finding means to avoid the patent and thus to save royalty payments.

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Making Money—Pilot plants are often built for the purpose of providing some revenue, with a relatively modest capital expenditure, to help finance product development which might otherwise be prohibitively expensive. Experimenting plays a relatively secondary role in such cases. Expenditures for experimenting must be carefully controlled lest, under the guise of process improvements, more money is spent than is made.

Training Ground—One of the great contributions that a properly conceived and operated pilot plant can make toward the development of a new idea or a new raw material or product is the fact that it can serve as a training school for the future operating staff; labor as well as technical.

Starting a plant with a completely green operating crew is not desirable. In a large chemical plant costly errors can be made by inexperienced operators, with loss of time, materials and damage to equipment and machinery. Control factors, techniques in manipulation, the effect of variables should be taught to operators in the pilot-scale plant.

Suggestions, often made by relatively untrained operators in a new plant can frequently improve the technical man's solution; and such contributions, sometimes of great value, are almost impossible to get in the laboratory.

Research Should Sit Back

This brings up another point worth giving some thought to—proper staffing of the pilot plant.

Constant control is of course essential. Therefore, it goes without saying that adequate staff and facilities for control and evaluation must be provided. But the control function should not be too much concerned with operational problems. The research department, with all due respect, should sit back and act largely in a consulting capacity. If their work was properly done originally, only relatively few research problems should arise in the pilot plant. As already mentioned, the pilot plant should not answer the question "Can it be done?", but "How can it be done best in the shortest time?". The research department should have already answered the first, and at least part of the second.

Far too often, the research man abandons some of his brains at the door of the pilot plant. He understands it is the place to make errors and proceeds to make many mistakes—even some utterly unreasonable ones. The plant man and the engineer do the same thing, and the pilot plant operator is the victim.

Under normal conditions, the man who will eventually carry the responsibility for the design of the ultimate plant should also play a major role in the design of the pilot plant. And he should therefore be very closely allied to its operation.

If the pilot plant is to serve fully it should be so conceived that every element of the organization having ultimate responsibility can contribute and can benefit.

The design of a pilot plant that will function adequately is an important study in itself. Unfortunately too little attention has been paid to it. Presumably this is based on the assumption that the good sense of all concerned will arrive at a reasonable compromise and that such a compromise will be the thing desired. The mere fact that it is a compromise does not guarantee its value.

The basic purpose of the pilot plant thus is to enlarge the laboratory experiments and to shrink the fill-scale operation—we may then, as Baekeland said, make our mistakes on a small scale in order that our profits will be on a large one. The intermediate stage must always have some logical and evaluable relation to each of the ends. This is not easy, and requires thoughtful consideration both of a technical and economical nature. When it is achieved, it provides vital information on which all members of the policy-forming group of a company can base sound decisions.

General Classification System . . . **And Comparative Ratings of Hard-Surfacing Alloys**

Designation	Hardness	General Atmospheric Corrosion Resistance	Resistance to Earth Abrasion	Resistance to Hot Deformation	Service Under Heavy Abrasion	Service in Sliding & Rolling Wear
Ferrous						
Hardenable Alloys						
Fe1. Carbon steels						
a. Low carbon	10	10	10	10	10	20
b. Medium carbon	10-40	10	10	10	10	50
c. High carbon	20-60	10	20	10	10	50
Fe2. Low-alloy steels						
a. Low carbon	10	10	10	10	10	30
b. Medium carbon	20-40	10	10	10	20	50
c. High carbon	20-60	10	20	20	20	50
d. Cast iron types	20-60	10	40	20	20	40
Fe3. Medium-high alloy steels						
a. Medium carbon	20-40	20	20	30	50	60
b. High carbon	30-50	20	40	50	80	60
c. Cast iron types	30-70	20	50	60	50	40
Fe4. High-alloy steels						
a. Low carbon	20-40	20-50	20	40	30	40
b. Medium carbon	30-60	20-30	40	50	70	60
c. High carbon	40-80	20-30	60	50	80	40
d. Cast iron types	40-80	20-30	70	50	50	40
Fe5. High-speed steels	80	20	40	70	40	40
Austenitic Steels						
FeCr1. Chromium and chromium-nickel						
a. Low carbon	30	90-100	20	20	30	30
b. High carbon, low nickel	40	90-100	20	40	50	30
c. High carbon, high nickel	40	90-100	30	40	50	30
FeMn, High manganese	40	50	20	20	80	50
Austenitic—Not Usually Heat Treated						
FeCr2. High-chromium iron*	60	60-80	70	80	80	80
Non-Ferrous						
CoCr Cobalt-base alloys						
A. Low alloy	40	90-100	50	100	80	90-100
B. High alloy	70	90-100	70	100	60	100
WC Carbides						
A. Inserts	100	60-80	100	100	50	100
B. Composite	75-100	30-60	100	—	70	—
C. Powder	—	—	100	—	70	—
Cu Copper-base alloys						
A. Copper-zinc	20	60-80	20	10	10	80-100
B. Copper-silicon	25	60-80	20	10	10	50-70
C. Copper-aluminum	25-40	60-80	30	10	10	70-90
Ni Nickel-base alloys						
A. Nickel-copper (Monel)	20	80-100	20	10	20	20
B. Ni-Cr (Nichrome)	30	80-100	40	70	40	60
C. Ni-Cr-W-Mo (Hastelloy)	50	90-100	50	90	60	*80

Welding Handbook, Third Edition, p. 472 (American Welding Society).
*Low carbon—up to 0.19 % C, medium carbon—0.20 to 0.60% C, high carbon—0.61 to 2.00% C, cast iron—over 2.00% C.

Selecting Wear-Resistant Materials

Basis for intelligent choice of hard-surfacing alloys for process equipment available in proposed AWS-ASTM specifications.

W. L. LUTES and H. F. REID, Jr., The McKay Co.

For years chemical engineers have been recommending and using hard-surfacing materials to extend the service life of valuable process equipment subjected to the damaging effects of corrosion, erosion, abrasion, impact, and other forms of wear.

Yet, the engineer's efforts frequently have been hampered by the lack of factual information regarding the composition and comparative properties of the various commercial alloys. There have been no industry-wide standards by which alloys could be appraised or compared. The sixty or more companies manufacturing hard-surfacing materials have attempted to solve the problems of wear from numerous, and sometimes widely divergent, approaches. Analysis of individual alloys was considered a trade secret. Comparison charts were incomplete and frequently contradictory. Net result was technical confusion, with past experience fre-

Wear Factors

- Abrasion resistance.
- Impact resistance.
- Metal-to-metal wear.
- Combinations of impact, abrasion, anP frictional wear resistance.
- Hardness.
- Chemical analysis and structure.
- Hot hardness or heat resistance.
- Initial surfacing cost.
- Ultimate service life.

quently the only aid in making recommendations.

A joint committee of the American Welding Society and American Society for Testing Materials has recently been engaged in drafting two tentative specifications for hard-surfacing materials.

Industry-wide acceptance of these specifications should provide a sound basis for the comparison of reputedly similar electrodes produced by the various manufacturers. Comparison is based on the chemical composition of the weld deposit. The compositional ranges are such that although marked variations in performance still can exist within any specific class of electrodes, the general problems encountered in selection have been minimized.

Selection of the best class of electrodes for any specific application still will depend on a combination of past experience, knowledge of the service conditions, and appreciation of the complexity of wear problems.

This article seeks to acquaint chemical engineers with this trend toward standardization, and to stress the advantages which may accrue from selecting the best iron-base materials for surfacing applications in process industries.

The discussion, for the most part, is limited to iron-base alloys. This limitation does not mean to infer that non-ferrous alloys cannot be used for surfacing application. Rather, it is felt that the actual and potential hard surfacing applications of non-ferrous alloys should be referred to those manufacturers specializing in the particular type of non-ferrous alloy in question.

General Characteristics

General classification system of the proposed specification provides for five main classes of coated electrodes. All iron-base materials are grouped in one main classification, Fe, and the non-ferrous alloys into four appropriate divisions as shown in the classification table. Thus a Class Fe3b electrode produced by manufacturer A should be approximately equivalent to electrodes of the same classification produced by other manufacturers. Differences in performance of the weld metal deposited by competitive electrodes might be encountered, particularly if the two deposits represented extremes of the compositional limit.

A definite relationship, for example, exists between the carbon content of the deposit and the abrasion resistance of any general classification of iron-base material. This relationship may be considered as a fundamental rule for comparing the effectiveness of iron-base alloys of the same general composition.

As the carbon content of the weld metal increases, abrasion resistance of the deposit increases. Increased abrasion resistance of the surfacing alloy is accompanied by a decrease in toughness (impact strength). This general rule holds only when comparing alloys of the same basic composition. It may not be valid when predicting the performance of two radically different alloys such as Class Fe2 (2% chromium steel) and Class Fe4 (12% chromium steel).

Properties

A detailed discussion of the complex metallurgical structure of the various types of materials used for hard-surfacing applications is beyond the scope of this article. Material composition will be related to various wear patterns with only limited reference to the actual metallurgical structure of the materials themselves.

The general term "hard-surfacing" implies that hardness is the major criterion for wear resistance. In some cases this is true. In other applications, however, other properties of the surfacing material (such as toughness, compressive strength, hot hardness) may be of greater importance than the standard Brinell or Rockwell hardness values.

Thus selection of materials based only on hardness information can be misleading. Abrasion resistance, as measured in field service or to a limited extent in the laboratory, is the only true criterion of wear resistance.

The general term "abrasion resistance" may be subdivided into eroding, grinding, gouging, and frictional abrasion. Each of these specific types of wear may be related, in turn, to somewhat specific metal compositions and structures.

Eroding Abrasion: Low-stress eroding abrasion occurs when fast-moving particles in streamlined flow scratch metal surfaces. Accumulation of these minute scratches produces a polished finish. If the material is in turbulent flow, the polished wear pattern will reflect the swirling of the abrasive particles and may even appear as fine grooves or swirl patterns.

Wear of this type frequently is encountered in air classifying or transporting equipment, in screw-feeds handling powdered materials, and in mining equipment used in sandy terrain.

Material to resist wear of this low-stress erosion type generally contains a rather high percentage of finely-divided complex carbides of chromium and chromium alloys such as found in Class Fe3d, Fe4d, and FeCr2 materials.

Grinding Abrasion: Grinding abrasion is a high-stress, scratch-type wear produced when abrasive material is caught between two hard moving faces. New sharp, angular faces continually are being formed on the abrasive material by

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the compressive forces of the grinding action. The abrasive particles scratch and gouge the softer faces, while the grinding stresses tend to fracture any brittle constituents in the grinding plates.

Wear of this type is found in crushing and grinding equipment. It also occurs in production machinery where dirt and grit have the opportunity to seep between moving faces, such as in the case of an un-lubricated sleeve bearing.

Martensitic steels and martensitic iron materials such as found in Fe3b, Fe4b and Fe4c materials do very well when subjected to this type of wear. They derive their wear resistance, to a large extent, from the toughness of the matrix material itself. They have a greater resistance to impact stress than the higher carbon alloys recommended for satisfactory abrasion.

Gouging Abrasion: Gouging abrasion, in a sense, is a magnified version of the gouging action of abrasive particles already described. Here, wear appears as long deep furrows that look as if the metal deliberately had been machined away. Wear of this type is characteristic of many types of digging and scraping equipment used in rocky or normal terrain.

Material to resist gouging abrasion must be both tough and hard. Materials of the austenitic manganese type (Class FeMn) or the manganese modified 18-8 type (Class FeCr1) meet these requirements. Both types of material are relatively soft (15-25 Rc) in their initial condition. The surface of the metal hardens rapidly to 50-55 Rc, under the repeated impact of the service conditions.

Hardening extends only a short distance below the surface of the metal. The main body of the overlay remains relatively soft, thus providing a cushion to absorb the impact stresses.

In a good many applications, the surface of the work-hardening material is overlaid with a thin layer of brittle wear-resisting material of Class Fe3c or Class Fe4d type. This overlay greatly increases wear life not only because of its own wear-resistant qualities, but also because it has protected the soft underlay until the underlay has absorbed sufficient impact to become work-hardened.

Frictional Abrasion: Resistance to frictional abrasion or galling requires an alloy that will take on extremely high polish, and possess high compressive strengths.

One of the most important uses for such surfacing alloys is in the production and repair of large valves for the hydraulic, petroleum and chemical industries. Class CoCr cobalt-chromium alloys are outstanding for this type of abrasion, with Class Fe4d and Class FeCr2 materials the best ferrous alloys for resistance to frictional abrasion. Guide rolls and roll conveyor equipment are typical applications.

Wear and Wear Factors

Selection of the best electrode for any given application depends on a favorable balancing of those factors, physical and economic, generally referred to as wear resistance. Each individual user of hard-surfacing materials defines wear resistance in terms of those factors affecting a particular application. Some factors most frequently mentioned are summarized in the table.

No single type of surfacing material combines the ultimate in all of these properties. Each class of electrodes has individual limitations, physical or economic.

The table of comparative ratings summarizes the general wearing properties of the various classes of surfacing overlays included in the proposed specification. The user, therefore, must select that combination of wear properties best suited for the application—which may be purchased at a price consistent with the operation.

All too frequently, users of hard surfacing materials unknowingly select and pay extra for specific properties not required for their application. For example, a large metal fabricator and repair shop had been using a highly-alloyed 12% chromium electrode for general purpose use. Service life of the resultant deposits more than justified the use of large quantities of relatively high-priced electrodes. Performance of the overlay was satisfactory.

Class Fe3c materials proved to be equally satisfactory with a savings of about $1.25 per pound of electrodes. The fabricators unknowingly were buying hot-hardness and high-temperature scale resistance not required for their application. Weld metal deposited by the less-

Applications to Equipment

Application	Classification
Fluid Flow	
Pipe joints, bends and turns	Fe2b, FeCr2
Pump housings	Fe2b, FeCr2
Valve seats and discs	CoCr, Fe4b
Hot oil pump sleeves	CoCr
Pump valves	CoCr
Refinery valve seating surfaces	CoCr
Centrifugal pump shafts and sleeves	Fe4b, CoCr
Mud, sand, and dredge pumps	Fe3b, FeCr2
Classifier screens	Fe3b
Pump impellers	Fe3b
Pump sleeves	Fe3d
Movement and Storage of Dry Materials	
Conveyor buckets	Fe2b, Fe3b
Tractor shoes and rollers	Fe2b
Mine car wheels	Fe2b
Mine rails	Fe2b
Craneways	Fe2b
Bucket bins	Fe3b
Quarry conveying equipment	Fe3b, Fe3d
Rail frogs, switches, and crossing	FeMn, FeCr
Dipper teeth, lips	FeMn, Fe3d
Tractor rollers	FeMn
Dipper teeth, etc. (sand and gravel)	Fe3d
Conveyor sprockets	Fe3d, Fe4d, FeCr1
Mattocks and shovels	Fe3b
Truck bodies	Fe3d
Clutch lugs	Fe3d
Cable sheaves	Fe3d
Power shovel crawler pads	Fe4d
Gear teeth	Fe4d
Fan blades	Fe4d
Conveyor sleeves	FeMn
Chutes (gravel, coal, etc.)	FeMn
Overlays on cast-iron	FeMn, FeCr1
Hoist guides	FeCr2
Extruding dies	Fe5
Crushing, Grinding and Mixing	
Mixer blade build-up	Fe2b
Crusher roll build-up	Fe2b
Impact crusher mills	Fe3b
Crusher jaws	Fe3b, FeCr2
Gyratory crushers	Fe3b, FeCr2
Sizing screens	Fe3b
Crusher rolls	FeMn, Fe3d, FeCr2
Crusher convaves	FeMn
Scraper and shredder knives	Fe3d, FeCr2
Muller tires	Fe3d, FeCr2
Mixer blades	Fe3d, Fe4d
Hammer-mill hammers	Fe3d, FeMn
Pulverizer rolls	Fe4b
Pug mill paddles	Fe4d
Pulverizer jaws	Fe4d
Grizzlies	Fe4d
Baffle plates	Fe4d

expensive electrode had the greater high-stress abrasion resistance vital to success of their application.

Similar re-evaluation of current hard-surfacing applications in process industries presumably might be one of the first direct results of application of the proposed standards.

Moving and Storage of Liquids

The general problems of wear relating to the flow and storage of liquids center around chemical attack, erosion, and metal-to-metal wear. Chromium and chromium-nickel alloy steels frequently are the preferred materials.

The continued, rapid expansion of the use of stainless steel in chemical industries is proof of the success of these specialized alloys in combating a wide range of problems involving chemical attack.

Theoretically, a large percentage of the chromium and chromium-nickel stainless alloys currently available could be sold at Class FeCr1a hard-surfacing electrodes. Large scale re-classification of conventional stainless steel filler metals is not anticipated or to be desired.

Availability of such a classification area does provide a potential means of standardizing those alloys of this type not now covered by existing stainless steel specifications.

Three classes of iron-base hard surfacing electrodes have proved effective in combating erosion type wear. Class Fe4b weld deposits (medium-carbon 5-chrome alloys) are preferred for erosion conditions also involving moderately-heavy impact and a moderate amount of heavy-stress abrasive action.

If the amount of impact decreases and the abrasive wear increases, then the wear areas should be surfaced using either Class Fe4d or Class FeCr2 (high-chromium iron) materials. High-chromium iron alloys for hard-surfacing applications is one of the newer developments in this field. Use of such materials for applications involving extremely severe abrasive action is increasing steadily.

Highly-alloyed cobalt-base materials are perhaps the most widely accepted non-ferrous alloy used for erosion type applications.

A few specific illustrations of applications for hard-surfacing materials in the handling of liquids are summarized in the applications table.

Movement and Storage of Solids

Movement and storage of solids may involve combinations of impact, abrasion and metal-to-metal wear in all degrees of severity. The problem extends from the pick and shovel or the power shovel used in mining the raw materials to the conveyor used to load the finished material for shipment.

Class Fe4b (medium-carbon, 12-chrome alloy) and Class Fe3b (medium-carbon, 5-chrome alloy) materials frequently are used almost interchangeably for applications involving heavy impact combined with a moderate amount of abrasion—such as found in the case of elevator pan-type conveyors.

If the impact is accompanied by a heavy abrasive action, then work-hardening Class FeMn materials are preferred. Shovel bucket teeth are a typical example of this latter type of wear.

The problem of extremely-heavy abrasion with limited amounts of impact has been solved by the use of Class Fe4d (very high carbon, 12-chrome) and Class Fe3c (very high carbon, 5-chrome) weld deposit. High-chromium iron alloys (Class FeCr2) are also frequently used for this type of application, as well as for those involving excessive metal-to-metal wear.

Cobalt-base non-ferrous alloys also are employed for such metal-to-metal service conditions. Conveyor screws are a typical example of this combination of metal-to-metal wear and heavy-stress abrasion.

The table summarizes but a few of the literally hundreds of applications of hard-surfacing materials to equipment used for the movement and storage of solid materials.

Crushing, Mixing and Grinding

Crushing, mixing, and grinding equipment are considered by many as possibly the chief service area for hard-surfacing materials. Maintenance of peak performance from equipment of this type is a constant problem in many phases of the chemical industry.

Wear to crushing, grinding, and mixing equipment generally involves impact and abrasion, with emphasis on the abrasive damage. Rock crushing balls used in quarry and open pit operations must withstand the severest type of impact with attendant abrasion. For such high-impact applications, Class FeMn alloys have proved their worth.

The abrasive action of equipment of this type frequently tasks the wear resistance of the most wear-resistant alloys. High-carbon Class Fe3d, Class Fe4d and Class FeCr2 hard-surfacing electrodes have proved the most popular alloys for the most severe applications.

Some specific recommendations for the maintenance of crushing, grinding, and mixing equipment are contained in the table.

High Temperature Applications

Thus far, the discussion of possible applications of hard-surfacing material to process industry equipment has referred to operations at or near normal room temperatures.

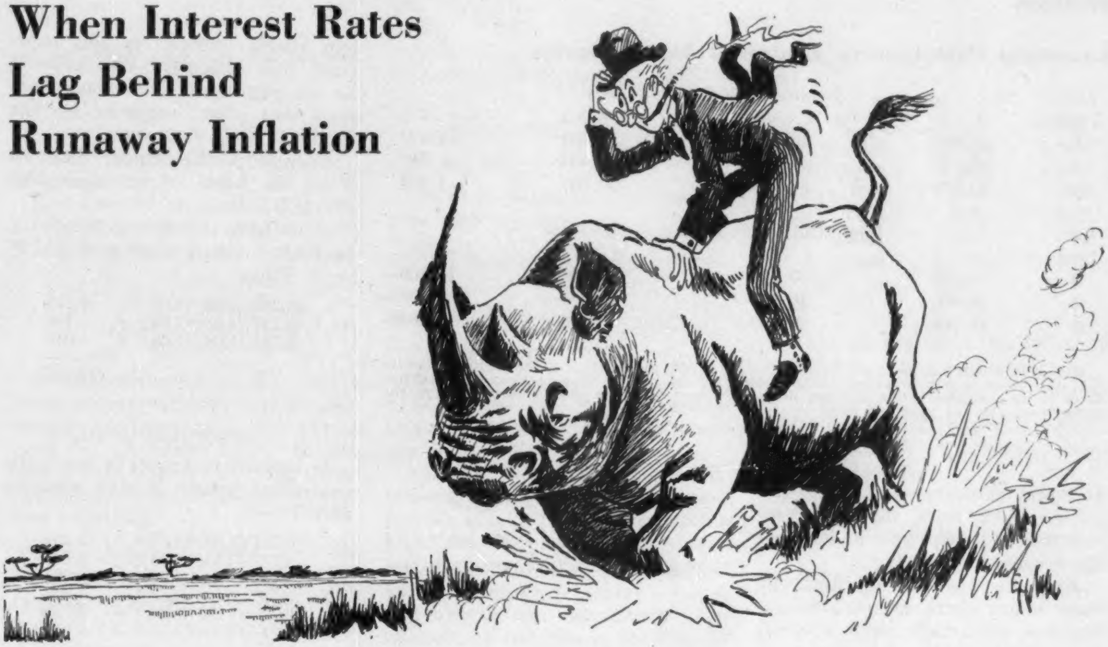
Actually, however, many of the wear problems encountered in the chemical industries are complicated and frequently accelerated by temperature of operation. Increased operating temperatures introduce the problem of surface oxidation and possible scaling.

Each class of hard-surfacing electrodes inherently has service temperature limitations, imposed by the chemical composition and metallurgical structure of the deposit.

In general, the oxidation resistance of many classes of hard-surfacing materials is related directly to the chromium content of the deposit. High chromium contents produce greater scale resistance. Class FeCr2 materials, containing approximately 30% chromium, may be used at 1,500 F. without danger of scaling. Non-ferrous alloys of the high-nickel, cobalt-base or nickel-molybdenum-tungsten variety frequently are used for such scale-resistant applications.

Maintenance of mechanical properties of the deposit, often evaluated in terms of hardness, is of equal importance in selecting a hard-surfacing material for high-temperature application. Class Fe3 and Class Fe4 materials retain their hardness to about 800 F. Class Fe5, which covers the high speed and tool steel analysis, may be used successfully to 1,000 F. Above 1,000 F., non-ferrous alloys should be used for such applications.

When Interest Rates Lag Behind Runaway Inflation



Watch Your Cost Analyses

Once it gets started, inflation has a way of getting worse. For your cost analyses covering this ugly situation use the capitalized cost method given here. It's valid when interest lags the decaying dollar.

F. C. JELEN, Solvay Process Div., Allied Chemical & Dye Corp.

When the decay rate of the dollar is greater than the interest rate that money accumulates with time, there is no limit to what we can afford to pay for an article that lasts forever. This has nothing to do with capitalized cost comparisons. It is merely a statement of fact.

However, it does mean that our concept of capitalized cost comparison as described in previous articles (*Chem. Eng.*, Feb. 1954, p. 199; Aug. 1955, p. 181; and May 1956, p. 165) leads us to an indefinite solution when the interest rate, i, is smaller than the decay rate of the dollar, d, expressed as a decimal.

Capitalized cost represents the first cost of an item plus the present value of an indefinite number of renewals—or more broadly, the price we can afford to pay for an article that lasts forever.

When d is greater than i, the capitalized cost as just defined becomes infinite. And we shall have to find some way of circumventing this impasse. We can do this by applying the principle of *equivalent yearly burden* introduced last month (*Chem. Eng.*, May 1956, p. 168).

Equivalent yearly burden can be defined as an equivalent end-of-year annual cost which increases by the factor $(1 + d)$ each year. This in turn will lead us to the concept of *extended capitalized cost* which we can use just like any other capitalized cost when $d > i$.

In the table on the top of the next page we list how much we can afford to pay for articles that last five and ten years when an article costs $10,000 initially and lasts one year, money being worth 8% per year. We see that when inflation is a factor, we can afford to pay more for the article that has the longer service life.

Moreover, the higher the rate of inflation, the more we can afford to pay. And this holds true whether d is smaller than or greater than i. The equivalent yearly burden is $10,800⟶ in all cases. (The arrow alongside the burden figure is to emphasize that it increases by the factor $(1 + d)$ each year. When there is no inflation, $d = 0$, we can drop the arrow and the annual cost remains the same.)

Equivalent Yearly Burden

Equivalent yearly burden is the key to how we can make cost comparisons when ugly inflation—like

Equivalent First Cost vs. Equivalent Yearly Burden

Life, Years	Equivalent First Cost, Dollars $d = 0$	$d = 4\%$	$d = 8\%$	$d = 12\%$
1	10,000	10,000	10,000	10,000
5	43,120	46,420	50,000	53,840
10	72,470	84,880	100,000	118,420

Life, Years	Equivalent Yearly Burden, Dollars/Year $d = 0$	$d = 4\%$	$d = 8\%$	$d = 12\%$
1	10,800	10,800→	10,800→	10,800→
5	10,800	10,800→	10,800→	10,800→
10	10,800	10,800→	10,800→	10,800→

Money is worth 8% per year ($i = 0.08$). An arrow alongside a dollar value indicates that the value is not constant, but increases by the factor $(1 + d)$ each year. When there is no inflation, $d = 0$, we can drop the arrow and the yearly cost remains the same from year to year.

an angry rhinoceros—starts to run away. We'll work through three examples to help you understand the concept more fully.

Example 1—Consider first the case where there is no inflation. Suppose an article costs $10,000, lasts three years and money is worth 8% per year. Last month we showed that three uniform end-of-year annual payments of $3,881 will exactly repay the $10,000 initial cost. The first payment of $3,881 at the end of the first year will draw interest for two years. The second payment will draw interest for one year and the third payment will draw no interest at all.

At the end of three years we will have $12,597.

$$\begin{array}{rl}(3{,}881)(1.08)^2 = & 4{,}525\\ (3{,}881)(1.08)^1 = & 4{,}191\\ (3{,}881)(1.08)^0 = & 3{,}881\\ \hline & \$12{,}597\end{array}$$

The original $10,000 is also worth $12,597 at the end of the three-year period.

$$(10{,}000)(1.08)^3 = \$12{,}597$$

Even if we have in mind six years of service, the yearly cost remains $3,881, because $3,881 paid at the end of the year for each of six years amounts to a total of $28,466.

$$\begin{array}{rl}(3{,}881)(1.08)^5 = & 5{,}702\\ (3{,}881)(1.08)^4 = & 5{,}280\\ (3{,}881)(1.08)^3 = & 4{,}887\\ (3{,}881)(1.08)^2 = & 4{,}525\\ (3{,}881)(1.08)^1 = & 4{,}191\\ (3{,}881)(1.08)^0 = & 3{,}881\\ \hline & \$28{,}466\end{array}$$

And $28,466 is exactly what $10,000 paid at the beginning of the six-year period, and another $10,000 paid at the end of the third year would be worth at the end of six years.

$$\begin{array}{rl}(10{,}000)(1.08)^6 = & 15{,}869\\ (10{,}000)(1.08)^3 = & 12{,}597\\ \hline & \$28{,}466\end{array}$$

This shows us that when inflation is not a factor, the equivalent *uniform* end-of-year annual cost represents the yearly cost whether we replace in kind or not.

Example 2—Reconsider Example 1 on the basis of a 4% per year inflation rate and a uniform end-of-year annual cost.

The uniform end-of-year annual cost for an initial installation only is $3,881. Calculations are the same as in Example 1.

If we have in mind six years of service, we will have to buy the first unit for $10,000 and three years later we must purchase a second unit which—because of inflation—will cost

$$\$10{,}000(1.04)^3 = \$11{,}249.$$

A uniform end-of-year annual payment of $4,095 will pay for both units.

$$\begin{array}{rl}(4{,}095)(1.08)^5 = & 6{,}016\\ (4{,}095)(1.08)^4 = & 5{,}571\\ (4{,}095)(1.08)^3 = & 5{,}158\\ (4{,}095)(1.08)^2 = & 4{,}776\\ (4{,}095)(1.08)^1 = & 4{,}423\\ (4{,}095)(1.08)^0 = & 4{,}095\\ \hline & \$30{,}039\end{array}$$

Also,

$$\begin{array}{rl}(10{,}000)(1.08)^6 = & 15{,}869\\ (10{,}000)(1.04)^3(1.08)^3 = & 14{,}170\\ \hline & \$30{,}039\end{array}$$

The equivalent uniform end-of-year annual cost is $3,881 for a three-year period and $4,095 for a six-year period. That is, when inflation is a factor, an equivalent uniform annual cost is not really uniform.

In our discussion last month we introduced the concept of "equivalent yearly burden" to help overcome this difficulty. We define it as an equivalent end-of-year annual cost that increases by the factor $(1 + d)$ each year.

Example 3—Reconsider Example 2 on the basis of an equivalent yearly burden.

If we have one unit in mind, the equivalent yearly burden is $3,737 ⟶. Thus,

$$\begin{array}{rl}(3{,}737)(1.04)^0(1.08)^2 = & 4{,}359\\ (3{,}737)(1.04)^1(1.08)^1 = & 4{,}196\\ (3{,}737)(1.04)^2(1.08)^0 = & 4{,}042\\ \hline & \$12{,}597\end{array}$$

and

$$(10{,}000)(1.08)^3 = \$12{,}597$$

If we have two units in mind, the equivalent yearly burden remains $3,737⟶.

$$\begin{array}{rl}(3{,}737)(1.04)^0(1.08)^5 = & 5{,}491\\ (3{,}737)(1.04)^1(1.08)^4 = & 5{,}287\\ (3{,}737)(1.04)^2(1.08)^3 = & 5{,}091\\ (3{,}737)(1.04)^3(1.08)^2 = & 4{,}903\\ (3{,}737)(1.04)^4(1.08)^1 = & 4{,}720\\ (3{,}737)(1.04)^5(1.08)^0 = & 4{,}547\\ \hline & \$30{,}039\end{array}$$

and

$$\begin{array}{rl}(10{,}000)(1.08)^6 = & 15{,}869\\ (10{,}000)(1.04)^3(1.08)^3 = & 14{,}170\\ \hline & \$30{,}039\end{array}$$

From these calculations we see that $3,737⟶ is the equivalent yearly burden whether we have one or more units in mind. It is the yearly cost whether we replace in kind, replace by something else, or do not replace at all.

Burden of an Initial Cost

Now how do we estimate the equivalent yearly burden of an initial cost?

Suppose that an article costs C now; lasts m years; money is worth i per year expressed as a decimal; and the inflation rate is d per year expressed as a decimal. Let $k_{d,i}$ be the equivalent yearly burden. Then,

$$C(1+i)^m = k_{d,i}(1+i)^{m-1} + k_{d,i}(1+d)(1+i)^{m-2} + \cdots + k_{d,i}(1+d)^{m-1}(1+i)^{m-m} \quad (1)$$

In Eq. (1) the left-hand side is the value of the initial cost, C, at compound interest for m years. The right-hand side is the value of the equivalent yearly burden $k_{d,i}$ at the end of m years.

Eq. (1) can be condensed to the following form:

$$C(1+i)^m = k_{d,i} \sum_{a=1}^{a=m} (1+d)^{a-1}(1+m)^{m-a}$$

or we could condense the summation to this form:

$$C = k_{d,i}\left(\frac{1}{1+d}\right)\sum_{a=1}^{a=m}\left(\frac{1+d}{1+i}\right)^a \qquad (2)$$

The summation part of Eq. (2) is a finite geometric series and we can reduce Eq. (2) to

$$k_{d,i} = (d-i)C\,\frac{I_{m,i}}{I_{m,d}-I_{m,i}} \qquad (3)$$

where $I_{m,i} = (1+i)^m$
and $I_{m,d} = (1+d)^m$

In the derivation of Eq. (3) it is immaterial whether d is greater than or smaller than i. Eq. (3) is valid for all values of d. In the special case where $d = i$, the equation becomes indeterminate but it then reduces to

$$k_{d=i} = C(1+i)/m \qquad (4)$$

We can use Eqs. (3) and (4) for problems in comparative costs. The table on this page contains a few selected values of the I factor

$$I_{m,i} = (1+i)^m$$

for convenience in checking the numerical examples of this article.

Let's go through two examples in estimating some comparative cost alternatives.

Example 4—An article costs \$10,000 and lasts one year. How much can we afford to pay for an article that lasts ten years if money is worth 8% per year and inflation is 12% per year.

By using Eq. (3) we can find $k_{d,i}$ for the one-year article.

$$k_{d,i} = (0.12-0.08)(10{,}000)\,\frac{I_{1,8\%}}{I_{1,12\%}-I_{1,8\%}}$$

$$= (0.04)(10{,}000)\,\frac{1.08}{1.12-1.08}$$

$$k_{d,i} = \$10{,}800$$

Using the same $k_{d,i}$ for the ten-year article,

$$10{,}800 = (0.12-0.08)C\,\frac{I_{10,8\%}}{I_{10,12\%}-I_{10,8\%}}$$

$$10{,}800 = (0.04)C\,\frac{2.1589}{3.1058-2.1589}$$

$$C = \$118{,}420$$

Therefore, we can afford to pay \$118,420 for the ten-year article, and only \$10,000 if the article lasts but one year.

Example 5—An article costs \$10,000 and lasts one year. How much can we afford to pay for an article that lasts ten years if both interest and inflation rates are 8% per year?

By using Eq. (4) we can find the equivalent yearly burden for the one-year article.

$$k_{d=i} = (10{,}000)\,(1.08)/1$$

$$k_{d=i} = \$10{,}800$$

Using the same equivalent yearly burden for the ten-year article,

$$10{,}800 = C(1.08)/10$$

$$C = \$100{,}000$$

Worth Closer Study

As we have just shown, Eq. (3) can be used for making cost comparisons. However, Eq. (3) is so closely akin to capitalized cost that it will pay us to study it further.

When d is greater than i, $k_{d,i}$ is obviously positive. When i is greater than d, the quantity $(d-i)$ is negative; but so is the quantity

$$I_{m,d} - I_{m,i}$$

Therefore, the value of $k_{d,i}$ remains positive. To avoid the occurrence of negatives, we can write Eq. (3) as two equations:

$$k_d = (i-d)C\,\frac{I_{m,i}}{I_{m,i}-I_{m,d}} \qquad (5)$$

where $i > d$

$$k_{d>i} = (d-i)C\,\frac{I_{m,i}}{I_{m,d}-I_{m,i}} \qquad (6)$$

where $d > i$

Last month we worked out the case where i is greater than d for an initial cost of C. We found that the capitalized cost is

$$K_d = C\,\frac{I_{m,i}}{I_{m,i}-I_{m,d}} \qquad (7)$$

If we substitute Eq. (7) into Eq. (5) we arrive at the following equation:

$$k_d = (i-d)K_d \qquad (8)$$

which we also derived last month. Certainly then, Eq. (5) is related to capitalized cost.

A New Definition

This suggests immediately that we define a new term,

$$K_{d>i} = C\,\frac{I_{m,i}}{I_{m,d}-I_{m,i}} \qquad (9)$$

which, when substituted into Eq. (6), gives

$$k_{d>i} = (d-i)K_{d>i} \qquad (10)$$

Extended Capitalized Cost

In Eq. (9) we use "extended" capitalized cost for an article whose initial cost is C, that lasts m years and for the case where d is greater than i. By *extended capitalized cost* we mean that we have extended capitalized cost into the range where the dollar decays at a faster rate than it earns interest with time. In this range we can use Eq. (9) directly to make our cost comparisons.

Example 6—Reconsider Example 4 on the basis of extended capitalized cost.

Using Eq. (9) we find the extended capital cost of the one-year article.

$$K_{d>i} = 10{,}000\,\frac{I_{1,8\%}}{I_{1,12\%}-I_{1,8\%}}$$

$$= 10{,}000\,\frac{1.08}{1.12-1.08}$$

$$K_{d>i} = \$270{,}000$$

Using this same value of extended capitalized cost for the ten-year article,

$$270{,}000 = C\,\frac{I_{10,8\%}}{I_{10,12\%},-I_{10,8\%}}$$

$$270{,}000 = C\,\frac{2.1589}{3.1058-2.1589}$$

$$C = \$118{,}420$$

Selected Values of I Factor

$$I_{m,i} = (1+i)^m$$

m	$I_{m,4\%}$	$I_{m,8\%}$	$I_{m,12\%}$
1	1.0400	1.0800	1.1200
2	1.0816	1.1664	1.2544
3	1.1249	1.2597	1.4049
4	1.1699	1.3605	1.5735
5	1.2167	1.4693	1.7623
10	1.4802	2.1589	3.1058

Nomenclature

B_j	Cost during the j-th year, present dollars
C	Initial cost of a facility, dollars
d	Inflation rate, decimal per year
$F_{m,i}$	$1 + G_{m,i}$
$G_{m,i}$	$1/[(1+i)^m - 1]$
H	Periodic deferred cost, present dollars
i	Interest rate, decimal per year
$I_{m,i}$	$(1+i)^m$
j	Year in which B_j occurs
k	Equivalent yearly cost, $d = 0$
k_d	Equivalent yearly burden, $i > d$
$k_{d>i}$	Equivalent yearly burden, $d > i$
$k_{d=i}$	Equivalent yearly burden, $d = i$
K	Capitalized cost, $d = 0$
K_d	Capitalized cost, $i > d$
$K_{d>i}$	Capitalized cost, $d > i$
L	Salvage value, present dollars
m	Useful life of a facility, years
M	Fixed annual burden (or if $d = 0$, fixed annual expense) present dollars per year
p	Period over which H is deferred, years

Compare Capitalized Cost with Equivalent Yearly Burden

d, Percent	K, Dollars	K_d, Dollars	$K_{d>i}$, Dollars
0	48,510	48,510	
2		63,460	
4		93,420	
6		183,400	
7		363,400	
7.5		723,300	
7.75		1,443,300	
8.00		∞	∞
8.25			1,436,700
8.50			716,700
9			356,700
10			176,700
12			86,750
14			56,790

d, Percent	k, Dollars/Year	k_d, Dollars/Year	$k_{d>i}$, Dollars/Year
0	3,881	3,881	
2		3,808→	
4		3,737→	
6		3,667→	
7		3,634→	
7.5		3,617→	
7.75		3,608→	
8.00		3,600→	3,600→
8.25			3,592→
8.50			3,583→
9			3,567→
10			3,534→
12			3,470→
14			3,407→

Capitalized cost, K, and equivalent yearly burden, k, are given above for an article that has an initial cost of $10,000, lasts three years, money is worth 8% per year ($i = 0.08$) and d is the inflation rate per year. An arrow alongside a dollar value indicates that the value is not constant, but increases by the factor $(1 + d)$ each year. When there is no inflation, $d = 0$, we can drop the arrow and the yearly cost remains the same from year to year.

And this checks with the results that we obtained in Example 4.

How to Interpret

What is the interpretation of extended capitalized cost? Is it a true capitalized cost? Can we use it as a capitalized cost?

The extended capitalized cost is not a true capitalized cost because it is not the equivalent cost of an article that lasts forever. Indeed, when d is greater than i, the true capitalized cost is infinite because we can afford to pay an unlimited amount for an article that will last forever.

However, the extended capitalized cost can be used in place of a capitalized cost and it is instructive to see just what it means.

From Eq. (9) we have

$$K_{d>i} = C\frac{(1+i)^m}{(1+d)^m - (1+i)^m}$$

Now when

$$K_{d>i} = C$$

we have

$$\frac{(1+i)^m}{(1+d)^m - (1+i)^m} = 1$$

$$m = \frac{\log 2}{\log[(1+d)/(1+i)]} \qquad (11)$$

This means that the extended capitalized cost is the equivalent cost of an article that lasts

$$\frac{\log 2}{\log[(1+d)/(1+i)]} \text{ yrs.}$$

Capitalized Cost and Inflation

Assuming an initial cost of C, we have shown in earlier articles that the following equations are correct:

$$K = C(I_{m.i})/(I_{m.i} - 1)$$
where $d = 0$

$$K_d = C(I_{m.i})/I_{m.i} - I_{m.d})$$
where $i > d$

$$k = ik$$
where $d = 0$

and

$$k_d = (i - d)K_d$$
where $i > d$

Now, based on what we have presented in this article, we can add the following:

$$K_{d>i} = C\frac{I_{m.i}}{I_{m.d} - I_{m.i}}$$
where $d > i$

$$K_{d=i} = \infty$$
where $d = i$

$$k_{d>i} = (d - i)K_{d>i}$$
where $d > i$

and

$$k_{d=i} = (C/m)(1 + i)$$
where $d = i$

In these equations K and K_d are true capitalized costs. We provide also for extended capitalized cost. The notation k with or without subscripts is the equivalent yearly burden.

The equations listed above will encompass any value of d.

A Continuous Function

In the table on this page we have computed some capitalized costs and burdens based on an article that costs $10,000, lasts three years, with money worth 8% per year. The values have been computed on the basis of a changing inflation rate.

Our main purpose in preparing this table is to show the particular circumstances in the neighborhood of $d = i$. Note that at $d = i$ both the true and extended capitalized costs become infinite.

However, the equivalent yearly burden is a continuous function.

Not Only for Initial Cost

For an initial cost, C, of an article that lasts m years, we have shown that the extended capitalized cost is given by the following formula:

$$K_{d>i} = C\frac{I_{m.i}}{I_{m.d} - I_{m.i}} \qquad (9)$$

Also, we have shown that the capitalized cost for the situation

Checklist of Equations for Capitalized Cost and Equivalent Yearly Burden

Type of Cost	K	K_d	$K_{d>i}$	k	k_d	$k_{d=i}$	$k_{d>i}$
	$d = 0$	$i > d$	$d > i$	$d = 0$	$i > d$	$d = i$	$d > i$
Initial cost of an article lasting m years.	$CF_{m.i}$	$C \dfrac{I_{m.i}}{I_{m.i} - I_{m.d}}$	$-K_d$	iK	$(i - d) K_d$	$\dfrac{C}{m}(1 + i)$	$(d - i) K_{d>i}$
Yearly expense, M, Increases by factor $(1 + d)$ each year with inflation.	$MF_{1.i}$	$M \dfrac{1 + i}{i - d}$	$-K_d$	iK	$(i - d) K_d$	$M(1 + i)$	$(d - i) K_{d>i}$
Salvage value, L, present dollars, of an article that lasts m years.	$-LG_{m.i}$	$-L \dfrac{I_{m.d}}{I_{m.i} - I_{m.d}}$	$-K_d$	iK	$(i - d) K_d$	$-\dfrac{L}{m}(i+i)$	$(d - i) K_{d>i}$
Deferred cost, B_j, present dollars, occuring during j-th year for an article lasting m years.	$\dfrac{B_j F_{m.i}}{I_{(j-1).i}}$	$B_j I_{(j-1).d} \times \left(\dfrac{I_{(m-j+1).i}}{I_{m.i} - I_{m.d}}\right)$	$-K_d$	iK	$(i - d) K_d$	$\dfrac{B_j}{m}(1 + i)$	$(d - i) K_{d>i}$
Periodic deferred cost, H, present dollars, every p years and first starting after p years.	$HG_{p.i}$	$H \dfrac{I_{p.d}}{I_{p.i} - I_{p.d}}$	$-K_d$	iK	$(i - d) K_d$	$\dfrac{H}{p}(1 + i)$	$(d - i) K_{d>i}$
Periodic deferred cost, H, corrected for omission of last overhaul, for an article lasting m years.	$H(G_{p.i} - G_{m.i})$	$H\left(\dfrac{I_{p.d}}{I_{p.i} - I_{p.d}} - \dfrac{I_{m.d}}{I_{m.i} - I_{m.d}}\right)$	$-K_d$	iK	$(i - d) K_d$	$H(1 + i) \times \left(\dfrac{1}{p} - \dfrac{1}{m}\right)$	$(d - i) K_{d>i}$

where i is greater than d can be expressed as

$$K_d = C \frac{I_{m.i}}{I_{m.i} - I_{m.d}} \tag{7}$$

Therefore, when we are considering initial costs,

$$K_{d>i} = -K_d \tag{12}$$

But Eq. (12) is not limited to initial costs. It is true for any cost. This fact we now demonstrate.

Consider a cost B_j, present value, incurred during the j-th year for an article that lasts m years. Using the same method that led to the derivation of Eq. (9) we find that

$$K_{d>i} = B_j I_{(j-1).d} \frac{I_{(m-j+1).i}}{I_{m.d} - I_{m.i}} \tag{13}$$

Previously we found out that for the same conditions

$$K_d = B_j I_{(j-1).d} \frac{I_{(m-j+1).i}}{I_{m.i} - I_{m.d}} \tag{14}$$

Eq. (14) is merely the negative of Eq. (13). Therefore, in this case also we find that

$$K_{d>i} = -K_d$$

Now in any system, however complicated, we can always find the extended capitalized cost by repeated use of Eq. (13). If Eq. (12) is true for Eqs. (13) and (14)—which it is—it follows that Eq. (12) is always true.

That is, the extended capitalized cost for the situation where d is greater than i is always the negative of the corresponding K_d. It is positive because when d is greater than i, K_d is negative.

The reason that we use separate subscripts on K is to keep the factor for extended capitalized cost positive. In problems that involve both expenses and income, a negative capitalized cost—extended or not—must represent a net income.

Other Costs

Because Eq. (12) is always true, we can readily calculate the extended capitalized cost from the equations that we derived last month for K_d.

The chart on p. 251 gives the equations for extended capitalized cost embracing:

- Initial cost.
- Fixed annual cost.
- Salvage value.
- Deferred cost.

The chart is a summary of all the principal equations for capitalized cost, extended capitalized cost and equivalent yearly burden that we have presented in these articles.

When inflation is a factor, a cost

Half Life of the Dollar

Half Life of the Dollar, Years	Decay of the Dollar, % per Year
35.0	2
23.4	3
17.7	4
14.2	5
11.9	6
9.0	8
7.3	10
6.1	12
5.3	14
4.7	16
4.2	18
3.8	20

is not completely specified without identifying the time. We consistently use the present time for our basis. For example, in the equations for salvage value, L is what the salvage value would be worth in today's dollar if the salvage were available today. The equation takes care of the fact that the salvage value will actually be

$$L(1+d)^m$$

when it is realized m years hence.

When writing the equations for extended capitalized cost, it is merely necessary to take the negative value of K_d as given in the chart on p. 251. This is done most conveniently by multiplying the denominator by minus one. For example, in the case of salvage value

$$K_d = -L\frac{I_{m.d}}{I_{m.i} - I_{m.d}}$$

$$K_{d>i} = -L\frac{I_{m.d}}{I_{m.d} - I_{m.i}}$$

An Extensive Example

The example below demonstrates how various costs can be treated in one problem.

Example 7—A heat exchanger uses steel tubes that cost $10,000 and last four years with a $2,000 salvage value. Cost for cleaning the inside of the tubes is $3,000 per year. Every two years the outside of the tubes must be cleaned at a cost of $4,000. During the fourth year there is an extra maintenance expense of $1,500.

It is proposed to substitute alloy tubes that cost $95,000, last ten years and have a $20,000 salvage value. Maintenance for the alloy tubes is $1,000 per year and the savings from increased production are $6,000 per year giving a net expense of minus $5,000 per year.

All of the above costs are in terms of the present value of the dollar. Money is worth 8% per year.

Does it pay to install the alloy tubes if the inflation rate is 12% per year?

We'll work out the extended capitalized cost of the steel tubes.

$$C\frac{I_{4.8\%}}{I_{4.12\%} - I_{4.8\%}} =$$

$$10{,}000\frac{1.3605}{1.5735 - 1.3605} = 63{,}873$$

$$-L\frac{I_{4.12\%}}{I_{4.12\%} - I_{4.8\%}} =$$

$$-2{,}000\frac{1{,}5735}{1.5735 - 1.3605} = -14{,}775$$

$$M\left(\frac{1+i}{d-i}\right) =$$

$$3{,}000\frac{1.08}{0.12 - 0.08} = 81{,}000$$

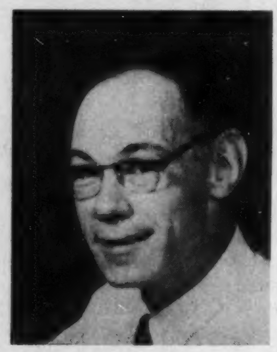
$$H\left(\frac{I_{2.12\%}}{I_{2.12\%} - I_{2.8\%}} - \frac{I_{4.12\%}}{I_{4.12\%} - I_{4.8\%}}\right) =$$

$$4{,}000\left(\frac{1.2544}{1.2544 - 1.1664} - \frac{1.5735}{1.5735 - 1.3605}\right) = 27{,}500$$

$$B_d I_{3.12\%}\frac{I_{1.8\%}}{I_{4.12\%} - I_{4.8\%}} =$$

$$(1{,}500)(1.4049)\frac{1.08}{1.5735 - 1.3605} = 10{,}685$$

$$K_{d>i} = \$168{,}283$$



FREDERIC C. JELEN presented the concept of capitalized cost and its use in replacement analyses in two earlier articles. Last month and this he extends these concepts to situations where inflation decays the value of the dollar. Dr. Jelen is a corrosion engineer with Solvay Process Div., Allied Chemical & Dye Corp., Syracuse, N. Y. A graduate of M.I.T. and Harvard, he is a licensed professional engineer in New York State.

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And now we can work out the extended capitalized cost for the alloy tubes.

$$C\frac{I_{10.8\%}}{I_{10.12\%} - I_{10.8\%}} =$$

$$(95{,}000)\frac{2.1589}{3.1058 - 2.1589} = 216{,}600$$

$$-L\frac{I_{10.12\%}}{I_{10.12\%} - I_{10.8\%}} =$$

$$-(20{,}000)\frac{3.1058}{3.1058 - 2.1589} = -65{,}600$$

$$M\left(\frac{1+i}{d-i}\right) =$$

$$-(5{,}000)\frac{1.08}{0.12 - 0.08} = -135{,}000$$

$$K_{d>i} = \$16{,}000$$

With $i = 8\%$ per year and with $d = 12\%$ per year, the extended capitalized cost for the steel tubes is $168,283 against $16,000 for the alloy tubes. Therefore, under these conditions, it will pay for us to install the alloy tubes.

For the special case where $d = i$, the extended capitalized cost cannot be used. Instead these problems must be evaluated, as in Example 5, on the basis of k, where d is equal to i. This is the equivalent yearly burden for $d = i$. The table on p. 251 gives the necessary equations for carrying through this calculation.

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Chemical Engineering Fundamentals

Reactor Design Problem: Stable Operation

Fluidized-bed reactors should be operated at gas velocities that result in stable conditions. Yes, but how do you design for this?

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THE USE of a fluidized catalyst may not, in all cases, be the panacea which some articles in the literature would lead us to believe. There are some disadvantages in the use of a fluidized-bed catalytic reactor.

Three difficulties which may occur in fluidization are slugging, channeling and attrition of the catalyst.

- Slugging is the term to describe what happens when gas passes up through the bed in the form of large gas bubbles.
- Channeling denotes the condition in which gas is not evenly distributed through the cross-section of the catalyst bed but is concentrated in channels through the bed.
- Excessive attrition may be caused by poor flow characteristics within the bed or by gas entering the bed in the form of jets rather than in evenly distributed flow.

These disadvantages of a fluidized-bed reactor can be minimized by proper design.

First we would design for longitudinal flow through the reactor. A longitudinal fluidized-bed reactor would fill the bill (see *Chem. Eng.*, April 1956, p. 202, Fig. 6).

This reactor has long parallel tubes that are filled with a fluidized catalyst. Passage of catalyst through the tubes is stabilized by an orifice at the bottom of each catalyst tube. To design a fluidized-bed reactor we would first calculate the required W/F value. (Where W is the mass of the catalyst and F is the feed rate to the reactor.) For this calculation we would use the conventional method.

However, there is more to the design than just obtaining the W/F value. Stable operation must be assured.

How to Avoid Instability

The reactor can be designed so that the operation will be stable. Insert a properly-sized orifice in the base of each tube.

What is the optimum size for the orifice? This is what we determined in our discussion last month (*Chem. Eng.*, May 1956, p. 203). We must pick an orifice that will give us a critical value of pressure drop across the catalyst tubes. This critical pressure drop corresponds to a design gas velocity that gives stable operation of the reactor. At this gas velocity, any sudden increase or decrease in the velocity will give an increase in pressure drop.

The effect will be to control the gas flow so that there will be no tendency for the flow through individual tubes to become unequal.

Try This Design Problem

To illustrate the concept of an optimum-size orifice we will work through the complete process design of a longitudinal fluidized-bed reactor.

Problem—Calculate the optimum-size orifice needed for a filled-tube fluidized bed made up of 4-in. pipe (Schedule 40), 20-ft. long tubes.

Pipe dimensions are:

Inside diameter	4.026 in.
Cross-sectional area	0.08840 sq. ft.

Our catalyst for the reaction is a synthetic petroleum cracking catalyst with these properties:

Particle diameter	83 microns
	(2.69×10^{-4} ft.)
Particle density	72 lb./cu. ft.
Bulk density	32.5 lb./cu. ft.

The properties of the reacting fluid at the conditions of the reaction are given as follows:

Viscosity	0.018 centipoise
	(1.21×10^{-5} lb. mass/ft.-sec.)
Density	0.075 lb./cu. ft.

Solution—The first step in our solution is to calculate the point of incipient fluidization. This corresponds to the gas velocity through the reactor which will equalize the pressure drop through the catalyst bed with the weight of the catalyst bed.

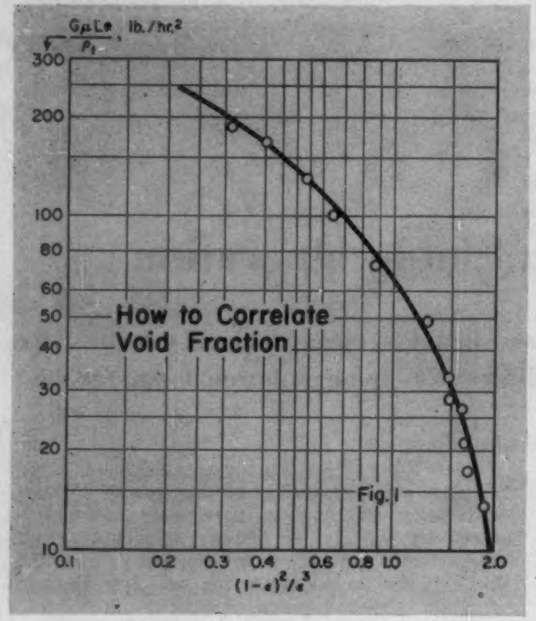
The pressure drop through the catalyst bed is found as follows:

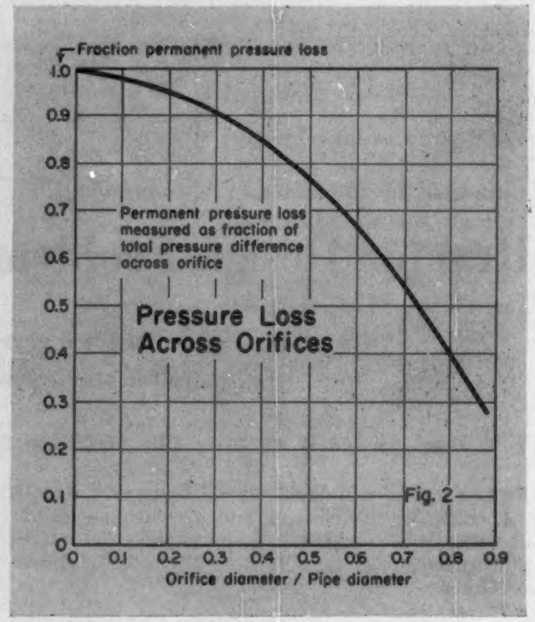
$$\Delta P = \text{Bed depth} \times \text{Bulk density}$$
$$= (20)\ (32.5) = 650 \text{ lb./sq. ft.}$$
$$\Delta P = 4.51 \text{ psi.}$$

Once we know the pressure drop, we can calculate the gas velocity at the point of incipient fluidization. Use this equation:[1]

$$\Delta P = \frac{200\, G\, \mu\, \lambda^2 L\, (1 - \epsilon)^2}{D_p^2\, \rho_f g\, \epsilon^3}$$

where ΔP = pressure drop, lb./sq. ft.; μ = fluid





viscosity, lb. mass/ft.-sec.; L = tube length, ft.; λ = shape factor, dimensionless; ϵ = catalyst void fraction, dimensionless; D_p = diameter of particles, ft.; ρ_f = fluid density, lb./cu. ft.; and g is the gravitation constant, ft./sec.²

We have been given enough information to evaluate all of these unknowns. We find that:

$$\begin{aligned}
\Delta P &= 650 \text{ lb./sq. ft.} \\
\mu &= 1.21 \times 10^{-6} \text{ lb. mass/ft.-sec.} \\
L &= 20 \text{ ft.} \\
\lambda &= 1.0 \\
\epsilon &= 0.549 \\
D_p &= 2.69 \times 10^{-4} \text{ ft.} \\
\rho_f &= 0.075 \text{ lb./cu. ft.} \\
g &= 32.2 \text{ ft./sec.}^2
\end{aligned}$$

And substituting in the equation,

$$650 = \frac{(200)\ (G)\ (1.21 \times 10^{-6})\ (1)^2\ (20)\ (1 - 0.549)^2}{(2.69 \times 10^{-4})^2\ (0.075)\ (32.2)\ (0.549)^3}$$

Nomenclature (Consistent Units)

C_o	Orifice coefficient
D_o	Orifice diameter
D_t	Tube diameter
D_p	Particle diameter
F	Feed rate
g	Universal gravitational constant
G	Gas mass rate of flow
L	Reactor tube length
Le	Bed expansion ratio, final bed height/initial bed height
ΔP	Pressure drop
ΔP_f	Pressure drop at point of incipient fluidization
v	Gas velocity
W	Mass of catalyst
ϵ	Catalyst void fraction
λ	Shape factor for catalyst particles
μ	Viscosity
ρ_f	Fluid density

The units check out as shown by substituting in the following equality:

$$\frac{\text{lb.}}{\text{sq. ft.}} = \frac{200\ G\ (\text{lb. mass/ft.-sec.})\ (\text{ft.})}{(\text{ft.}^2)\ (\text{lb./cu. ft.})\ (\text{ft./sec.}^2)}$$

Units of G = lb./sq. ft.-sec.

$$G = 1.90 \times 10^{-6} \text{ lb./sq. ft.-sec.}$$

This gives us the mass rate of flow, which we convert to the gas velocity through the reactor.

$$v = G/\rho_f$$

$$v = \frac{1.9 \times 10^{-3} \text{ lb./sq. ft.-sec.}}{0.075 \text{ lb./cu. ft.}}$$

$$v = 0.0254 \text{ ft./sec.}$$

Therefore, the conditions at the point of incipient fluidization are:

Pressure Drop	650 lb./sq. ft. or, 4.51 psi.
Velocity	0.0254 ft./sec.

What Happens As Fluidization Progresses?

As the gas velocity increases beyond the velocity required for incipient fluidization, the bed expands and the pressure drop per foot of bed height decreases. The pressure drop is still—for all practical purposes—the weight of the bed, but we must determine the new bulk density.

It's best to get these data from actual experimental results. However, if you do not have such data available you can estimate with the aid of Fig. 1, above.

This plot was first developed by Leva and his co-workers, and later modified by Clarke and Beckman at the Carnegie Institute of Technology.[8] The symbol Le represents the bed expansion ratio or final bed height divided by the initial bed height.

Since Le is directly related to the catalyst void fraction, ϵ, if we assume values for ϵ we can

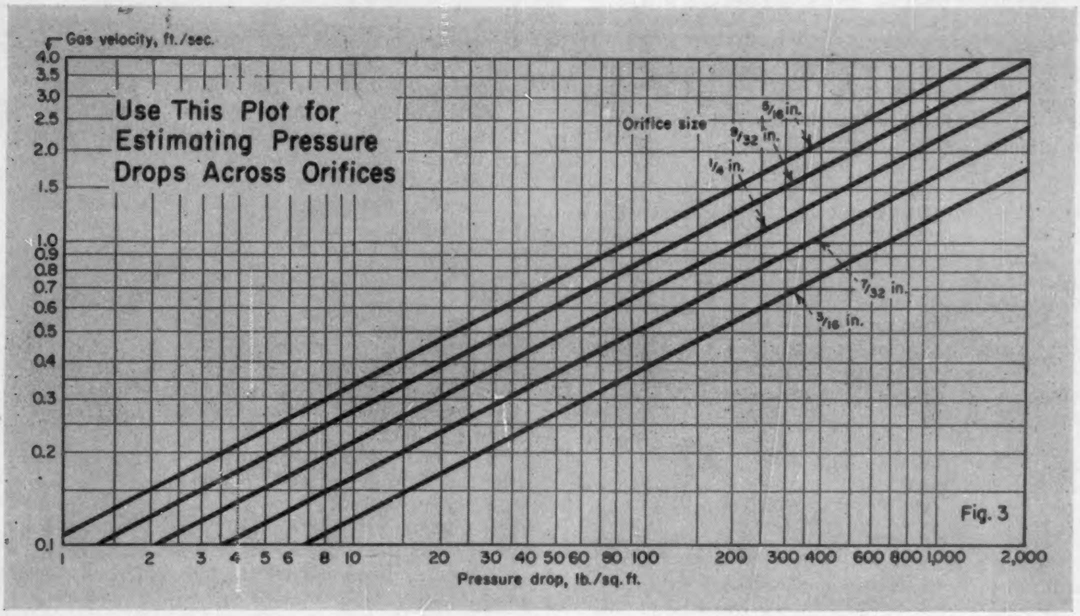


Fig. 3

calculate values of the gas mass rate of flow, G, and hence values for gas velocity, v.

Also, when we know the value of Le, we can calculate the pressure drop that corresponds to various fluid velocities in a tube of fixed length. Use this relationship:

$$\Delta P = \Delta P_f/Le$$

That is, the pressure drop at any velocity is equal to the pressure drop at incipient fluidization divided by the bed expansion ratio.

Tabulate and Calculate

Let us now tabulate some assumed values of catalyst void fraction, ϵ, and calculate the velocities and pressure drops that would be needed to produce these values.

ϵ	$1-\epsilon$	$(1-\epsilon)^2$	ϵ^3	$\frac{(1-\epsilon)^2}{\epsilon^3}$	$\frac{G\,\mu\,Le}{\rho_f}$
0.55	0.45	0.202	0.166	1.22	45
0.58	0.42	0.176	0.195	0.903	72
0.60	0.40	0.160	0.216	0.741	88
0.64	0.36	0.130	0.262	0.496	141
0.68	0.32	0.102	0.313	0.326	185

Please note that in the table above the values for the quantity $G\mu\, Le/\rho_f$ are given in terms of lb./hr.² This, in turn, will lead to values of G expressed as lb./hr.-sq. ft. in the table that follows.

Le	G, lb./sq. ft.-hr.	v, ft./sec.	ΔP, lb./sq. ft.	ΔP, psi.
1.002	0.0215	0.286	648	4.50
1.082	0.0318	0.424	600	4.17
1.129	0.0373	0.497	576	4.00
1.253	0.0539	0.719	519	3.60
1.410	0.0627	0.836	460	3.19

These values compare reasonably well with some actual experimental data that have been reported in the literature. (Matheson, G. L., W. A. Herbst and P. H. Holt, 2nd, "Characteristics of Fluid-Solid Systems," *Ind. & Eng. Chem.*, 41, pp. 1,099-1,104, June 1949.)

v, ft./sec.	ΔP, psi.
0.1	4.16
0.4	3.89
0.6	3.75
0.8	3.61
1.0	3.47

Since we have actual experimental data available, we will use them in the rest of this calculation.

Calculate Orifice Pressure Drop

Next we must calculate the pressure drops that correspond to various sizes of orifices. We can simplify these calculations as follows:

We can use the standard orifice equation,

$$v = C_o\left(\frac{2g\,\Delta P/\rho_f}{(D_t^4/D_o^4)-1}\right)^{0.5}$$

where C_o is the orifice coefficient; D_t is the tube diameter; and D_o is the orifice diameter.

In most calculations, it is reasonable to assume that $C_o = 0.61$. For a particular size orifice, the ratio D_t/D_o is a constant and therefore D_t^4/D_o^4 is a constant. Also, ρ_f, the density of the fluid is a constant.

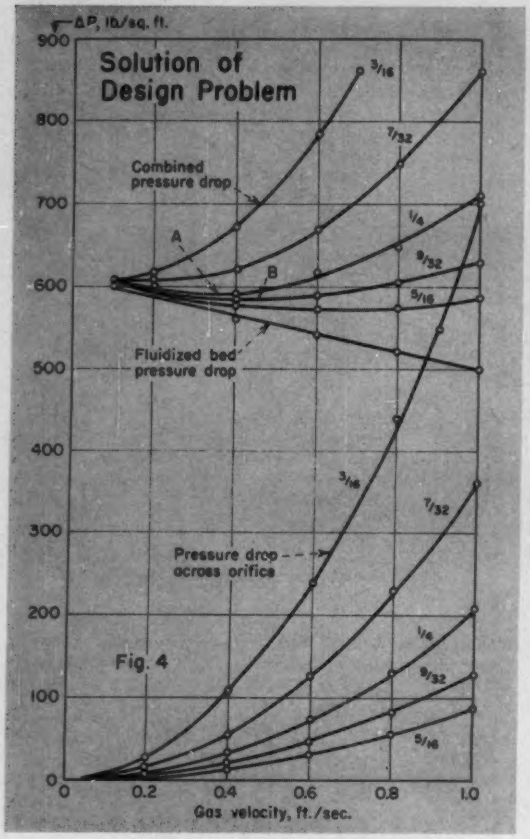
Therefore, the formula reduces to

$$v = K_1\,(\Delta P)^{0.5}$$

where

$$K_1 = C_o\left(\frac{2g}{\rho[(D_t^4/D_o^4)-1]}\right)^{0.5}$$

If the ratio of diameters D_t/D_o, is less than



5.0, we must incorporate a factor to determine the permanent pressure loss. We can obtain this factor from Fig. 2. Once we obtain the factor, it becomes part of K_1 for any given orifice size.

Now, if we take the logarithm of both sides of our equation, we obtain the following form:

$$\log v = 0.5 \log \Delta P + \log K_1$$

Thus, if we plot velocity against pressure drop for a given size orifice, we will get a straight line on log-log paper. This line will have a slope of 0.5.

We have done this in Fig. 3 for orifice sizes 3/16 in., 7/32 in., 1/4 in., 9/32 in. and 5/16 in.

And Now the Final Solution

The final solution of the problem is shown in Fig. 4 above. First we plot the actual experimental data for the pressure drop due to the catalyst bed alone. Then we plot the pressure drop due to the use of various size orifices. Finally, we show a combined plot of the pressure drop due to the bed added to the pressure drop caused by each orifice.

Note that the 3/16-in. and 7/32-in. orifices give pressure drop curves which when added to the bed pressure drop curves do not exhibit a minimum.

Therefore, these orifices are too small to stabilize this system. The total pressure-drop curves for 1/4-in. and 9/32-in. orifices both show minimums at gas velocities of 0.36 and 0.46 ft./sec, respectively. This corresponds to 590 and 585 lb./sq. ft., respectively. (*Points A and B, Fig.* 4.)

Either of these orifices would give stable operation at approximately these conditions, since either an increase or a decrease in velocity would cause an increase in total pressure drop.

The total pressure-drop curve for a 5/16-in. orifice exhibits little or no minimum. This size orifice—as well as all larger sizes—are too big to stabilize this reactor system.

An Alternate Method

An alternative method for calculating pressure drop due to the bed alone may be found in "Unit Operations" by G. G. Brown, et al., p. 271 and 272 with Fig. 281.

This method is based on the assumption that at the free-settling velocity for the catalyst particles, the porosity may be assumed to be unity. A plot can then be prepared of log porosity vs. log Reynolds' number. The portion of the curve between the point of incipient fluidization and the point of free settling is assumed to be a straight line.

Then, the remainder of the problem can be worked out using the same method that we have illustrated in this discussion.

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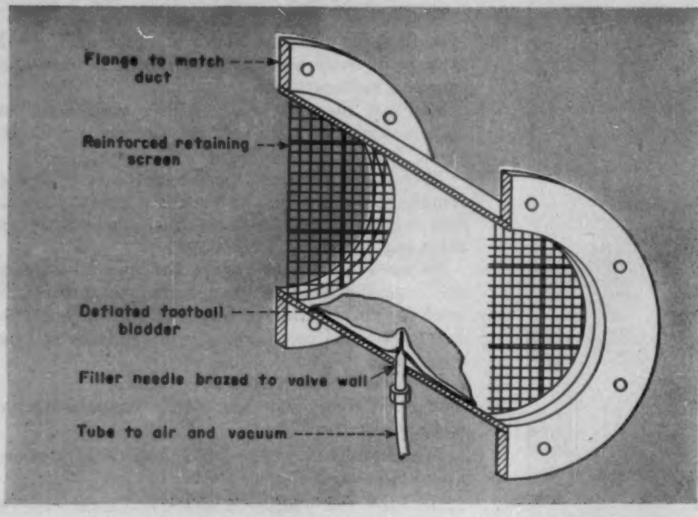
1. Leva, Grummer, Weintraub and Pollichick, "Introduction to Fluidization and Fluidization of Solid Non-Vesicular Particles," *U. S. Bureau of Mines, Report*, No. 3,035 : Q 59.

2. Clarke, W. M. and R. B. Beckman, "Pressure Drop Investigation of Fluidized Beds," Unpublished senior student report, *Carnegie Institute of Technology*, Pittsburgh, Pa., June 1950.

NOTE—*We wish to refer you to a letter from Gunvant C. Sutaria calling our attention to an error that appeared in our Oct.* 1955 *installment on General Considerations in Reactor Design. Mr. Sutaria's letter and an answer from Dr. Corrigan appear this month in the Pro & Con pages. Please see page* 426. *Next month we'll present some worked-out problems that show how to use the kinetic rate equations to size catalytic reactors*—EDITOR.



★ Winner of March Contest

"Bladder Valve" Seals Circular Ducts

Disclosed here is a simple, low-cost way of valving medium sized circular ducts, using a football bladder as closure.

Victor Pratt

Chemical Engineer, Engineering Research Div., Fort Detrick, Frederick, Md.

In the operation of certain test chambers we had to purge the gaseous contents periodically to reduce the concentration of contaminants before starting another series of tests.

The chamber was equipped with 6-in. sheet metal ducts for air supply and exhaust, by means of which purging air was blown in and withdrawn. It was desirable to have remote-operated valves in both ducts to control the purging process. However, the nature of the equipment made it necessary that the valves be very light in weight. Also, they should give positive shutoff, and be reasonable in cost. No leakage of exhaust air through any part of the valve would be permissible.

We knew of no commercially available valve which would meet all these requirements. On that account it was necessary to design and build a new type valve which we called a "bladder valve" because of the nature of the sealing element. This is simply a small football bladder which is installed in an 8-in. long section of circular duct. The duct section is flanged at both ends for connection into the process duct. The filler needle (supplied with the football for inflating) is brazed through the valve wall in such a way that a copper tube fitting can be attached on the outside.

At either end of the 8-in. long valve body a retaining screen is mounted to limit the longitudinal expansion of the bladder when it is inflated, and to force the bladder to fill the valve cavity. Since the bladder is elastic, it will fill the valve entirely, taking the shape of the valve body, and producing a tight seal.

In the sketch it will be noted that a copper line is attached to the filler needle. This line is routed to a control panel where it can be supplied with either 2-psig. air for inflation, or 20 in. Hg vacuum for deflation of the bladder.

Valves of this type have been used satisfactorily for over 5 years. Bladder replacement has been required only once or twice per year. However, attempts to use this principle for larger valves, with larger bladders, have been of limited usefulness owing to variable quality of the rubber. Instead, successful valving of larger ducts has been accomplished by manifolding a sufficient number of valves of the 6-in. size.

★ Winner of April Contest—Gerald A. Lessells

"Ternary Mixture Chart Finds Weight and Mole Fractions"

How Readers Can Win . . .

$50 Prize for a Good Idea—Until further notice the Editors of *Chemical Engineering*, will award $50 cash each month to the author of the best short article received that month and accepted for the Plant Notebook.

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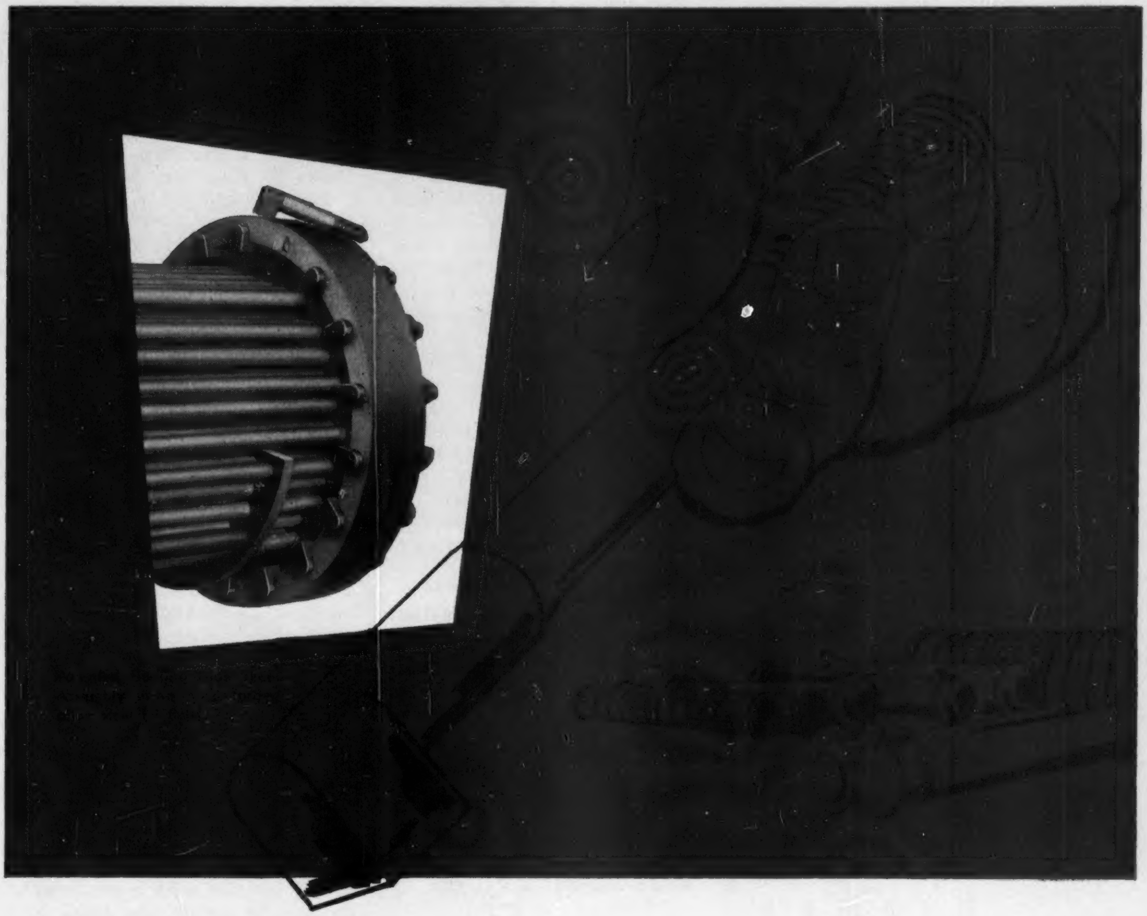

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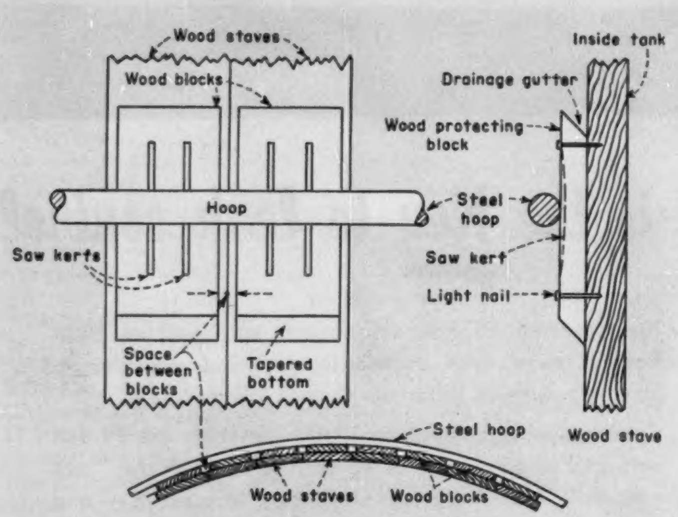
Dale S. Davis
Professor of Chemical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

As the practice of chemical engineering becomes more complex, technical journals become still more valuable to the chemical engineer. Although he may be tempted to clip material of current interest as it appears, a little thought will convince him that his later interests will probably be different, and therefore it is best to keep the journals intact and perhaps bind them.

Having done so, he can then make them even more valuable. Get together the journals for a previous period, say 10 years, and spend 15 minutes a day turning the pages. Your changing interests will point out material which previously meant little to you. Follow this procedure every two years and you will find that back issues will provide a wealth of information of present need.

One important point, however: Make sure you *turn the pages.* Don't merely scan the contents pages.

(Editor's Note—It is a fact well known to technical magazine editors that the life of technical articles may be very long. This is attested to by the large number of requests editors receive for tear sheets, reprints and photostats, long after the article originally appeared. Now Dr. Davis proposes a still more efficient way of making capital of your back files of technical magazines.)



Protect Your Tank Hoops From Corrosion

Donald F. Othmer
Head of Chemical Engineering Dept., Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Steel hoops which hold together the staves of wooden tanks present a corrosion problem unless some method of protection is used. Two such methods having lead protectors, one a pipe sleeve, the other an "umbrella," were shown on p. 230 of the March 1956 issue of *Chemical Engineering.* Both are probably good, but have objections, especially at the threaded ends of the hoops. Also, capillarity may prevent drainage of any corrosive liquid that gets between the hoop and the lead.

Several plants have standardized on the protection method shown here for all wood stave tanks. The method is used even for water and relatively noncorrosive brines or other solutions. It is cheaper and is successful with many other liquids which attack lead.

It consists in using pillow blocks of wood to hold the hoops away from the staves. The blocks are 6 to 8 in. long, cut from $\frac{3}{4}$ to $1\frac{1}{2}$-in. board, and are about $\frac{1}{2}$ in. narrower than the staves. Each block is tapered as shown at top and bottom. The top taper forms a gutter to direct any liquid overflow or leakage down the sides of the blocks. Sometimes one or more saw kerfs, made with a circular saw, will be added to allow better drainage. When the blocks are installed the gaps between them span the cracks between the staves so that most liquid leaks run down the cracks themselves.

When the blocks are installed, each is initially held in the proper location with a couple of light nails before the hoop is put in place. Assembly is easy compared with lead coverings. The hoop connector straddles two or more of the blocks, depending on its length and the width of the staves.

Watch Those Automatic Descending Doors

Paul C. Ziemke
Safety Engineer, Oak Ridge, Tenn.

Most design engineers follow the old, time-tried practice of wiring vertical motor-operated doors with a lock-in type of pushbutton control. Although this arrangement ordinarily works very well indeed, there are occasions when it can be exceedingly dangerous. Momentary contact on the pushbutton will open the door wide until the upper limit switch stops it at the top of its travel. Conversely, just a touch on the button will start the door closing, until the lower limit switch stops it in the

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closed position. Trouble can come, and has on several occasions, when the door operator is unaware of a second person about to pass through as he starts the door's descent.

The chance for trouble is especially likely when the pushbutton is in a remote location. An engineer making a final inspection of a process about to go on the line was struck squarely on the bridge of the nose by a descending door that someone had started from a remote location. His expensive, special-prescription glasses were broken and he went to the hospital with a brain concussion. A warehouseman started the door down and returned to his desk as an industrial truck roared around an exterior corner, drowning out the noise of the door mechanism and running into the half-closed door with loss of the door itself, and considerable damage to the truck.

The cure for this hazard is not far to seek. In the first place, the pushbutton should be at the door, and not in a remote location. In the second, the lock-in wire should be removed from the magnetic-switch relay so that the door-operating motor can run only as long as the button is depressed. In this way, the operator can see just who may be involved in the doorway, and he must remain at the button until the door is closed. The limit switches will still guard against the possibility that he is daydreaming and the arrangement will be completely safe.

Remember 10 Numbers for a "Mental Math Kit"

	Number (R_{10} Series)	Rank, Approx. 10 Log_{10}	4-Place 10 Log_{10}	Dimensions Mm.	Dimensions Inches	Logical Sequence R_5 Series	Logical Sequence "Gold No." Series
	0.63	−2	−2.007				
	0.8	−1	−0.869				
Memory Series	1	0	0			1	1
Memory Series	1.25	1	0.969				
Memory Series	1.6	2	2.041	1.6	1/16	1.6	1.618
Memory Series	2	3	3.010	2			
Memory Series	2.5	4	3.979	2.5		2.5	2.618
Memory Series	3.15	5	4.983	3.15	1/8		
Memory Series	4	6	6.021	4		4	4.236
Memory Series	5	7	6.990	5			
Memory Series	6.3	8	7.993	6.3	1/4	6.3	6.854
Memory Series	8	9	9.031	8			
Memory Series	10	10	10.000	10		10	11.090
	12.5	11	10.969	12.5	1/2		
	16	12	12.041				
	20	13	13.010				
	25	14	13.979	25	1		

"Magic Number" Series Speeds Calculation

C. Volff

Manager, Research & Control Dept., L'Air Liquide, Montreal, Canada.

If you can remember a simple series of 10 numbers, as shown in Col. (1) of the table above, you will have a set of mental logarithms which will help you make many calculations almost without mental effort. And in case you forget the series, you can write it down by recalling that it is an approximate geometric progression starting with 1, with an approximate ratio of 1.25 of one number to the next.

To convert this series (Col. 1 above) into a log table, you simply match each number with its rank, starting with zero for the first number and adding a digit for each succeeding number, as in Col. (2) of the table. These "rank" numbers are approximately 10 times the logarithms of the numbers in the first column. Column (3) shows how close is the correspondence of the actual four-place logs to the approximate logs. As with ordinary logs, the memory series can be extended either above or below the 1-to-10 series, as Cols. (1) to (3) of the table show.

How to Use the Logs

Multiply or Divide—To multiply two numbers, add their ranks.

> $1.25 \times 2.5 = 3.15$; adding ranks, $1 + 4 = 5$ ($= 10 \log_{10} 3.15$)
>
> $6.3 \div 2.5 = 2.5$; subtracting ranks, $8 - 4 = 4$.

Reciprocals—One number is the reciprocal of another if both are symmetrical about 3.15, i.e., the sum of their ranks is 10. One of the numbers must of course be divided by 10:

> 25 (rank 4) and 4/10 (rank 6) are reciprocal.

Using Pi—The number 3.15 is approximately π. So, to calculate a circle's circumference, add 5 to the rank of the diameter:

> Where $D = 1.6$, $\pi \times 1.6 = 5$; adding ranks, $5 + 2 = 7$.

To calculate a circle's area, double the rank of D and subtract 1.

> For $D = 1.6$, $1.6^2 \times \pi/4 = 2$; using ranks, $(2 + 2) + (5 - 6) = 3$.

Powers and Roots—Multiply the rank by the power, or divide by the root:

> $(1.6)^{2.5} = 3.15$; using the rank, $2 \times 2.5 = 5$.
>
> $(6.3^3)^{1/4} = 4$; using the rank, $(8 \times 3)/4 = 6$.

Finding Logs—Remembering that the tabulated values are $10(\log_{10})$ of the number, perform the indicated manipulations:

> $\log \sqrt{2} = 0.3/2 = 0.15$; $\log \sqrt[3]{4} = 0.6/3 = 0.2$; $\log 2^{4/3} = (0.3 \times 4)/3 = 0.4$.

Making Logarithmic Graphs—You can calibrate one or both coordinate axes of a graph logarithmically by using equally spaced grid lines marked off with the series 1, 1.25, 1.6, 2, 2.5 . . . 10. (However, this is harder to interpolate than the system used by Grogan, p. 212, May 1955, *Chemical Engineering*, where approximate logarithmic spacing resulted from the close coincidence of actual logs with various numbers of 40ths of the entire space.—*Editor.*)

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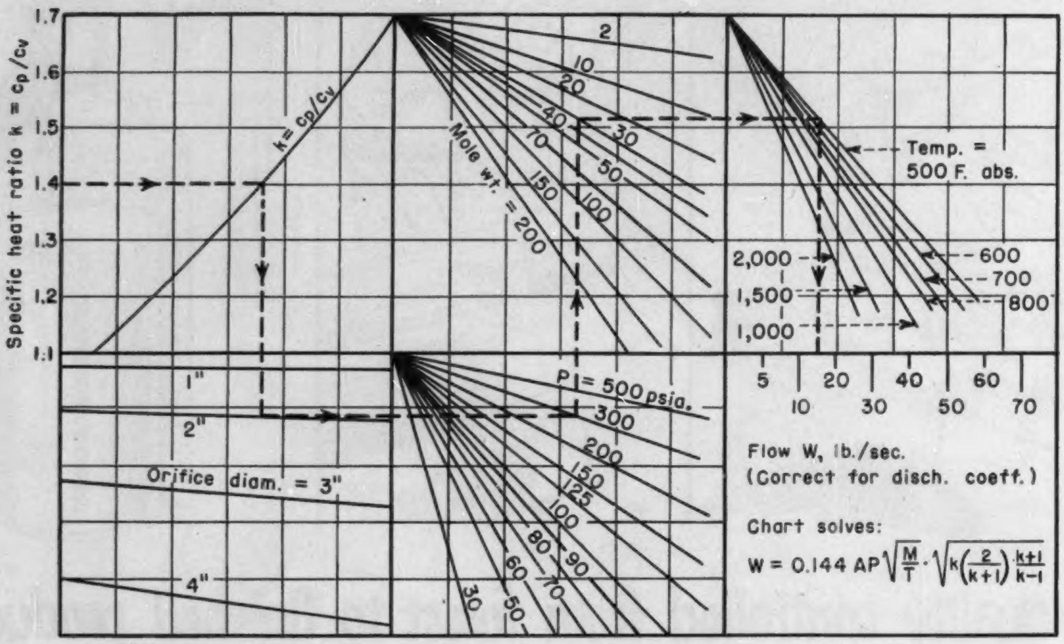
1 in. the series can be used for quick, approximate conversion of metric and English dimensions, as Cols. (4) and (5) of the table show. Hence 0.4 mm. = $\frac{1}{64}$ in.; 31.5 mm. = $1\frac{1}{4}$ in.; 63 mm. = $2\frac{1}{2}$ in., etc.

The R_5 Series—The 10-number series we have been discussing was devised by a Frenchman, Col. Renart, and is known as R_{10}. A similar series based on 20 numbers between 1 and 10 is called R_{20}, while the series of five numbers in Col. (6) is called R_5. This last series has the important property that each term is approximately the sum of the two terms preceding it, and the ratio of succeeding terms is about 1.6. The numbers are close to a perfect series of this type, shown in the last column of the table, where the ratio is 1.618, the "gold number" of the ancient Greeks, and each term exactly equals the sum of the two preceding terms.

This series gives a basis for designing a series of apparatus in logical sequence, where the sum of any two quantities in the series equals the next higher number, while the difference equals the next lower. For example, take two resistances of 1.6 and 2.5 ohms. Putting them in series gives a total resistance of 4. Putting them in parallel gives a total resistance of 1 ohm [$R = (1.6 \times 2.5)/(1.6 + 2.5) = 1$].



Gas Flow Chart for Orifices and Nozzles

Edward J. Gibbons
Mechanical Engineer, New York, N. Y.

Critical pressure ratio conditions exist in many gas-flow problems, for example, usually with long lines involving large pressure drops, as well as with relief valves, nozzles, and rupture disks protecting pressure vessels.

The solution to such problems is greatly expedited with the accompanying chart, especially if several trials are needed for optimum design.

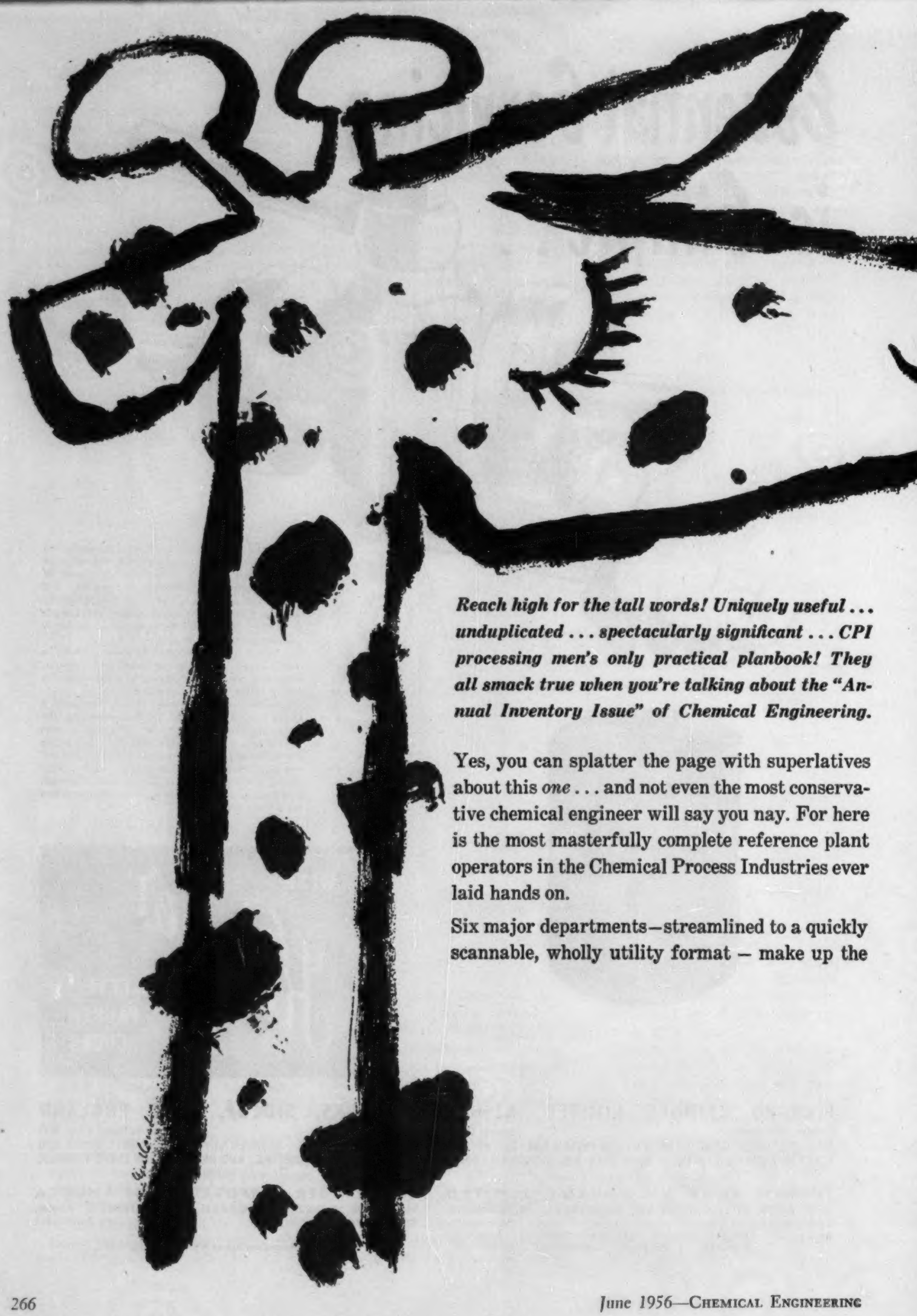
The chart is based on the rational equation shown, where W is the gas flow rate, lb./sec.; A is the orifice area, sq. in.; P is the upstream pressure, psia.; M is the molecular weight; T is the upstream gas temperature, °F. abs.; and k is the specific heat ratio, c_p/c_v.

The chart gives theoretical flow for a wide range of gases at varying temperatures and pressures. To get actual discharge the chart result must be multiplied by a suitable discharge coefficient varying from 0.6 to 0.99, depending upon whether an orifice or nozzle is used, as well as numerous other physical factors needing a separate evaluation.

The example drawn on the chart shows how much nitric oxide (k = 1.4) will flow from a 2-in. orifice with upstream pressure at 300 psia., and temperature at 500 F. abs. The result is 22.5 lb./sec.

The chart can also be used conversely to find the orifice or nozzle size, knowing the gas flow rate to be relieved.

Values of k are influenced by temperature and pressure. Normally k = 1.67 for monatomic gases; 1.4 for diatomic gases; 1.33 for polyatomic gases; and 1.1 for high molecular weight organics. For high temperatures (500 F.) and high pressures, k should be checked.



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The New Graduates: What They Know

Take advantage of the "new look" in chemical engineering education and you'll profit by using this year's graduates at their full capabilities.

In the next few days the nation's colleges and universities will award some 2,500 bachelor degrees in chemical engineering. And, in the coming weeks, most of the recipients will begin the all-important first job of their engineering careers.

How well they perform in this position, how well they begin their careers, is also vitally important to the firms that hire them. Already each new man represents a healthy investment in recruiting time and money—at least $2,000 per man is one oil company's estimate. And in the next few months—as they get their first real taste of engineering—decisions will be made which will greatly affect the course of each career.

Starting on the Right Foot

Invariably, the young engineer's first boss and early co-workers play major roles in shaping his ideas and attitudes toward his job, his company and his profession. The use that the company makes of his talents is another vital factor in determining whether or not his career gets off on the right foot. Help him to channel his enthusiasms, ambitions, talents and learning in the proper directions and he'll adapt to the work quicker and his future growth will be more sure.

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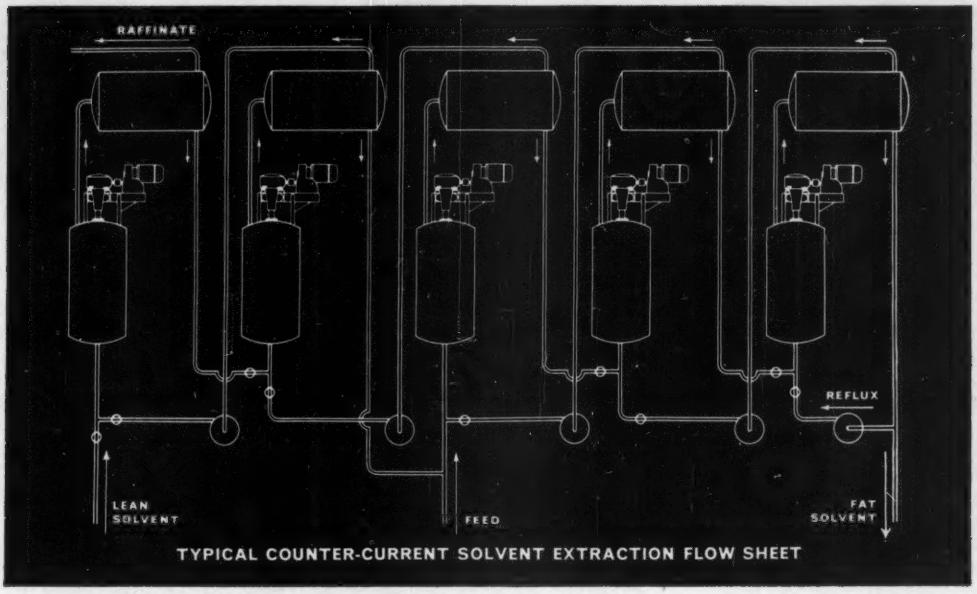

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exposed to, take advantage of its strengths, shore up its weak spots and you'll save a lot of your own time and make better use of him. And, importantly, you'll head off one of the major gripes of many an engineer—that he's not being used to his full capacity.

Education's Always Changing

Technical advances, shifts in industry's methods of using engineers and greater experience with the curriculum have teamed to work a number of changes in chemical engineering education. Although these changes have come gradually over the decades, chances are that this year's graduate has been exposed to course material somewhat different than you saw.

Courses once regarded as vital have been revamped or dropped completely to make room in the schedule for today's needs. Advances in the nuclear field, in reaction kinetics, in mathematics are showing up in the classroom in bigger doses.

Another trend is the move from the empirical to the theoretical. Engineering teachers have thrown up their hands at teaching details of engineering practice while knowing that what they teach may be out of date by graduation day. So increasingly they've been teaching the underlying theory in place of empirical methods.

Even the unit operations, up to now virtually the hallmark of the chemical engineering curriculum, are beginning to bow before this trend. In their place are coming courses in the "fundamentals" — mass, heat and momentum transfer, chemical thermodynamics, reaction kinetics, etc. In addition, basic sciences, notably math and physics, are claiming greater attention and more class time.

At the same time, the amount of time devoted to the strictly chemistry courses has shown a decline. Today's graduate has probably spent less time in the qualitative and quantiative analysis labs than you did.

None Are "Typical"

To complicate the picture no single curriculum can be considered typical. AIChE's Committee on Chemical Engineering Education and Accrediting has encouraged experimentation in curricula development and this has resulted in a variety of approaches based on local conditions, needs of local industries, strengths and weaknesses of the faculty, available facilities, etc.

But to get a better idea what the 1956 graduate studied let's retrace his steps since September 1952 and follow him from class to class for four years.

Enter the Frosh

Generally, the schools which grant degrees in chemical engineering have a common first year for all engineering students.

Unless the college requires entering students to be well versed in algebra and trigonometry, a combination course in these subjects makes up the first semester of math. Where conditions permit the school to insist on this pre-college preparation, analytical geometry is taught in the first semester.

In the first group of schools, analytical geometry is given in the second semester. Students in colleges of the second group move right into differential calculus in the second semester.

General chemistry is a two semester course in the first year. Generally, it concentrates on inorganic chemistry, with a relatively brief survey of organic winding up the second semester.

The general engineering course of the freshman year usually covers engineering drawing, including some freehand sketching, and descriptive geometry, with less emphasis on the latter. A number of schools also give hard-to-categorize courses in general engineering problems or in aspects of industrial engineering in this year or in the sophomore year.

English is about the on'. other course given in both freshman semesters in most schools. Depending on the school it will vary in content from grammer and composition to literature study. More and more schools are including instruction on technical writing in these courses.

Other freshmen year courses are generally one semester in length. For instance, surveying survives in a bare handful of chemical engineering curricula as a two-credit course. Public speaking, a foreign language, history, government and business or contract law are other examples.

Into the Sophomore Year

In those schools which give a semester of differential calculus to freshmen, the sophomore year consists of a semester of integral calculus and a semester of differential equations or some special course in advanced mathematics for engineers. The other schools give two semesters of calculus to sophomores and a growing number teach a special math course to juniors or seniors.

The sophomore chemical engineering student also takes about 10 credits in physics. Now, the course usually includes a few lectures on nuclear physics in addition to the usual work in mechanics, light, sound, heat, magnetism and electricity. A few schools feel this is now important enough to be worth a separate course later in the curriculum—sometimes as an elective.

Analytical Chemistry a Bulwark

Analytical chemistry, though on the decline, is still a sophomore year bulwark. Qualitative analysis is sometimes given at the end of the freshman course, but it often appears as a separate course for sophs. Quantitative analysis is nearly always given to sophs, usually in a four-credit, second semester course. But some schools give two semesters, four credits each.

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Development of special synthetic fabrics has extended the benefits of Wheelabrator cloth-tube efficiency to operations where hot and/or corrosive gases must be ventilated.

Available in a complete range of standard models, assembled and knock-down, Wheelabrator collectors are efficient for handling air at 250 cfm up to hundreds of thousands cfm. Special models are readily designed for special applications. For more information, write today for Catalog 372.

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The much-discussed process engineering course at the University of California doesn't include any quantitative analysis at all. This AIChE-accredited course is offered by the mechanical engineering department and is heavier in engineering and lighter in chemistry than any other accredited course.

The sophomore also takes courses in applied engineering mechanics. Statics, dynamics, strength of materials and, perhaps, structures make up the list. Statics is given in all schools and nearly all give strength of materials. Those that give dynamics generally defer strength of materials to the junior year. A course in structures is given in only a few schools.

General courses in economics are often given to sophomores. And a number of schools present a course in stoichiometry to the sophomores—their first exercise in chemical engineering. Often this course is called Industrial Chemical Calculations or something similar and comprises stoichiometry, material and energy balances and problems involving the handling chemical engineering data. At some schools it is given in two semesters; one in the sophomore year and one in the junior.

Variety Marks Later Years

It grows even more difficult to sketch a typical course in chemical engineering when you reach the junior year.

Several of the top schools give an advanced math course at this time. Others wait until the senior year. The course may cover differential equations, statistics, nomography, dimensional analysis, empirical equations and other methods of data processing.

Most schools give their courses in organic and physical chemistry in this year. The organic chemistry course usually includes at least a dozen laboratory preparations and a survey of biochemistry—in addition to the chemistry of hydrocarbons, substituted hydrocarbons, organic acids, substituted acids and polymers.

Physical chemistry courses are sometimes supplimented by other advanced chemistry courses, or spread over three semesters.

As mentioned above, strength of materials is often given in this year. A course in electrical engineering is almost sure to be given in the junior year. Usually it covers the generation of electromotive force, electrical circuits, motors and generators and electronics — although a few schools give a complete and separate course in electronics.

The courses in chemical engineering vary widely in content. Often a course title is so broad that it covers practically everything and the catalog description is so vague and ambiguous that it is difficult to know exactly what is being taught in each course.

Metallurgy or physical metallurgy is mostly given in the junior year. Sometimes material on corrosion—types of corrosion, measurement and prevention—is included in this course.

Starting Unit Operations

In many schools the junior year also holds the first of the three semesters of unit operations. Fluid flow and heat transfer are apt to be the first subjects treated, but a number of schools begin with a study of solids—properties, handling, size reduction, agglomeration—then take up fluids.

The senior year unit operations courses cover those operations involving mass transfer and simultaneous mass and energy transfer. All schools give a laboratory course in conjunction with the unit operations course.

Kinetics Given to Seniors

Chemical engineering thermodynamics is another senior year subject. However, as mentioned above, energy balances are sometimes covered in an earlier course on "calculations." Material on reaction kinetics is often taught along with thermodynamics, although a few schools assign it as a separate subject and others include it under other headings.

Instrumentation and process control often shows up as a separate subject but most schools prefer to include the bulk of this material in a process equipment design course. The latter may also include plant design and location, plant site needs, cost estimation, reactor design and/or comprehensive equipment design problems.

As mentioned, an advanced math course is often given to senior chemical engineering students. A handful of schools require a separate course in economic balances. And some schools still give a course which surveys current industrial processes and technology. Generally field inspection trips are run as part of such a course.

Nearly half of the schools require a senior thesis or project. Subject matter for these and the type of treatment required vary all over the lot. In some schools it involves an original research project in some field of physical chemistry or chemical engineering. In others it means designing and writing specifications

Next Month: Leveling the Obstacles to an Idea

The process of getting a creative idea is fraught with uncertainties and difficulties. Overcoming them has been made a bit easier by the tools and tricks that have been fashioned since thinkers started to consider creativity as a problem in its own right. Next month's You & Your Job will discuss those techniques that can help you skirt the trouble spots when you hunt for a good idea.

for a plant to carry out a designated chemical process. In others, a literature search is required.

Electives may be either technical or non-technical, and their number and variety (and the fact that the list may change from year to year) make it virtually impossible to categorize them or generalize about them. In most chemical engineering curriculas the non-technical courses, whether required or elective, make up 20-25% of the total credits.

Schools with ROTC programs often allow the required military courses to substitute for some of these electives. But with the Naval ROTC program these required military courses are so extensive that an extra year is needed to fit them into the student engineer's class roster.

The Five Year Programs

Four schools give a five year course to all chemical engineering students—Ohio State, Cornell, Rice Institute and the University of Minnesota. The added time is split between non-technical subjects, more chemical engineering courses more chemistry and more electrical engineering in about that order of precedence.

A handful of other schools are on the cooperative plan. These require just about the same number of credits as the four-year schools. In addition they require from 16 to 27 months of satisfactory work in local industry.

A growing number of institutions are pioneering the so-called "3-2" plan. Under this plan the student enrolls in a liberal arts college for three years and takes a non-specialized course in both the arts and sciences. At the end of his junior year he transfers to the engineering school of a university for two years of intensive engineering specialization. At graduation he is awarded a BS in engineering from the university and a BA degree from the liberal arts school.

Experience with graduates of this plan is as yet too limited to draw conclusions on its effectiveness, but it is being carefully watched.

Profit From It

This, then, is the type of background each new man is bringing to his new job. Wrapped up in the 125 to 160 credits (170 to 180 for five-year men) which he's earned are a strong grounding in science fundamentals, extensive preparation in math, long practice in working design calculations, some skill in handling chemical engineering data and a lot of confusion about what's actually going on in industry.

He needs orientation, he needs instruction at a practical level, he has to pick up the many empirical methods used in industry. His college could not hope to teach him all these things and still give him the background needed to fit into any segment of industry. Recognize this, know what he's bringing to his job, take advantage of it and you, your company and your profession will all come up winners.

TRAINING ENGINEERS

. . . As Executives

A program "designed to meet the needs of engineers who, within the next decade, will fill top executive positions in industry" will be given next September at the University of California at Los Angeles.

The graduate-level course will be limited to 30 men, each of whom must have a B.S. in engineering from an accredited school, a satisfactory grade point standing and a minimum of five years of industry experience in engineering. Applicants under 40 are preferred.

Prof. L. M. K. Boelter, Chairman of UCLA's Department of Engineering and the man to contact for more information, says that participants will have to spend a minimum of 15 hr./wk., outside of class time, on the program. He urges potential applicants to "assure themselves that their companies will agree to this magnitude of effort outside the regular job."

FLOATING HOLIDAYS

. . . Add Flexibility

"If a man wants a day off to take his family on a picnic, he'll be able to do it. Others who want a longer vacation can tack it on to their regular vacations".

That's how Abbott Labs president, Ernest H. Volwiler, sums up the advantages to his company's new holiday credit plan. The North Chicago, Ill., firm has added three paid holidays to the six "fixed" holidays which its employees have been getting. The three newcomers can be taken in half-day units as the employee wishes—so long as his superior approves.

Under the new plan all of Abbott's 4,200 employees in the United States have more flexibility in the use of their leisure hours.

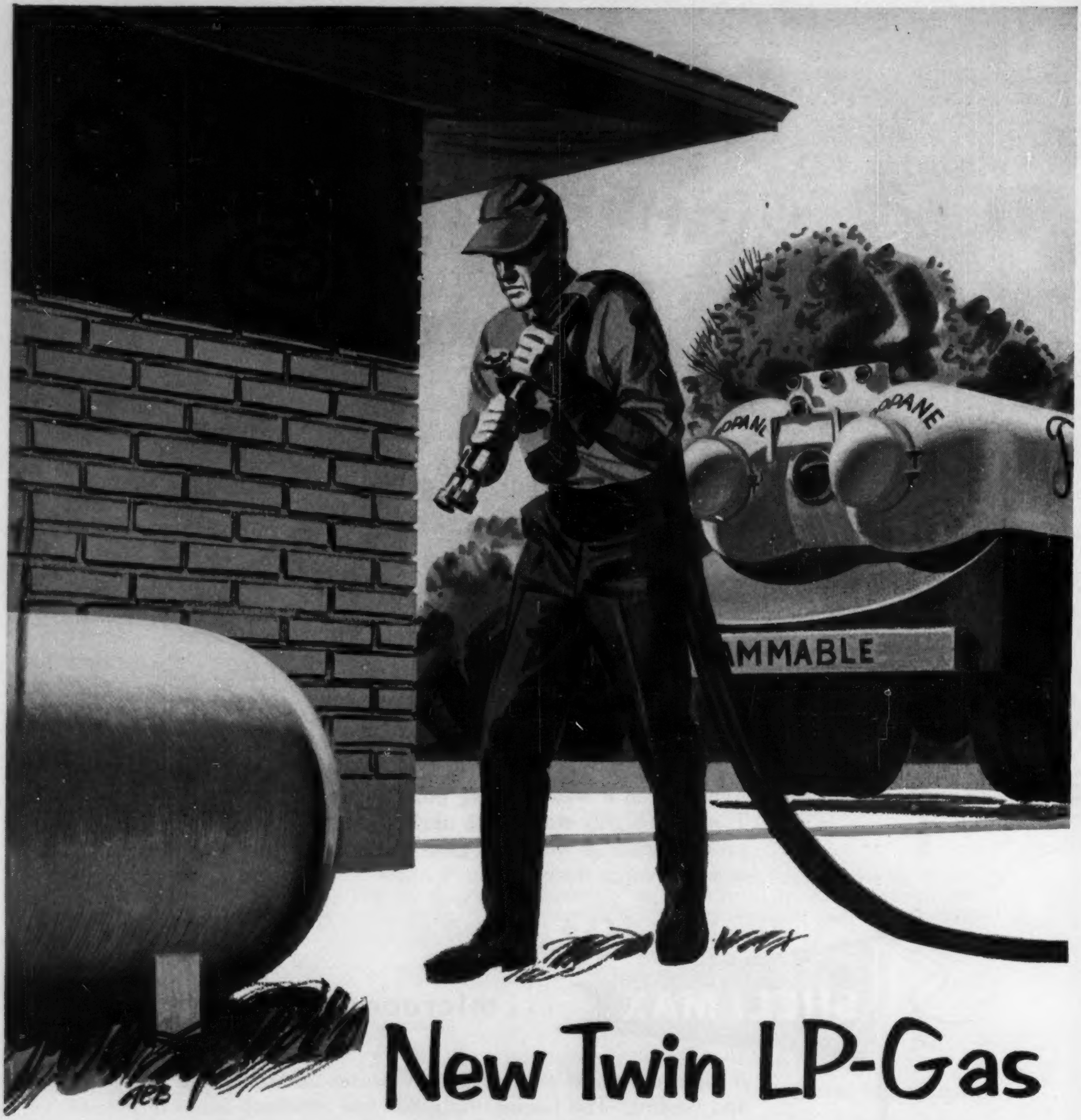
$500 REWARD

. . . Hiring Gimmick

Want an extra $500—legally?

That's what Maryland Electronic Manufacturing Corp., College Park, Md., is willing to pay to anyone who can get it a "competent electronic engineer." If the company hires the man you suggest, you get $500.

This is one of the latest devices cooked up by firms plagued by the shortage of specialized engineering talent. We haven't seen anything like it in the chemical industry yet. If we do, you'll be the first person we'll tell.



New Twin LP-Gas

Here's how to save money on vapor return systems now in use and get full efficiency out of hose trays and dual hose reels. New Hewitt-Robins *Twin* LPG Hose has liquid delivery and vapor return hoses firmly bonded into one easy-to-handle unit! "Straight-cured" by an exclusive process, it is safer, more flexible hose —won't writhe or twist! It plays out and rewinds smoothly, quickly, coils neatly—saves the driver's time and enables him to serve more customers per day. Strain on meter and pump is minimized because of low pressure differential.

Hewitt-Robins *Twin* LPG Hose has special nonporous synthetic tubes that provide full flow, that resist the permeating action of liquefied petroleum gases. High tensil rayon cord reinforces and adds extra service life to the strong carcass. To dissipate static effectively,

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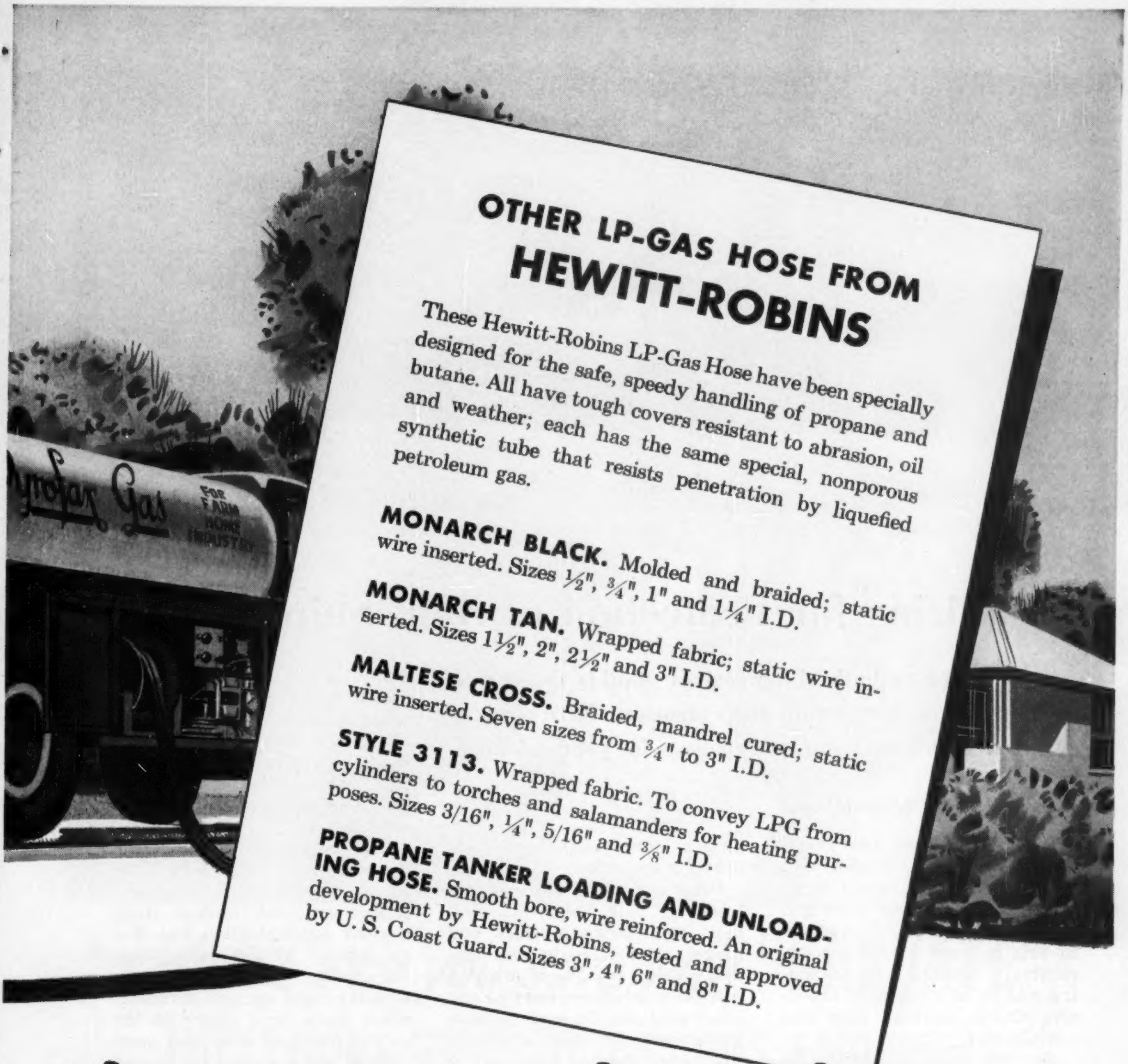

Hose wins wide acclaim

a spiral wire is embedded in the wall of the hose. The covers are black compound—oil, weather and abrasion resistant; won't harden, crack or peel. The twin lines are readily separated for convenience in installing couplings.

Hewitt-Robins *Twin* LPG Hose is another first from the leading manufacturer of petroleum hose. No more two-reel operation. No more taping of separate hoses on a single reel. No more tangled hose on trays. It is the perfect hose for vapor return delivery systems; can be used on any truck.

Sizes: ½" vapor and ¾" liquid.

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DESIGN, MANUFACTURE, ENGINEERING AND ERECTION OF COMPLETE BULK MATERIALS HANDLING SYSTEMS

Corrosion Forum

EDITED BY M. M. HOOVER

T-2 TANKERS, barge tanks, tank cars, and trailers for bulk liquid chemicals are protected by metallizing.

Metallizing for Protection of Bulk Shipments

Trend to bulk shipments of liquids poses new problems of contamination and corrosion. Here's recent experience with metal-sprayed coatings for your guidance.

H. S. Hammond, Metalweld, Inc.

During the past ten years, there has been a concentrated effort by a great many large chemical firms to find ways and means of shipping their products in bulk to lower shipping costs, eliminate handling and packaging and to do away with expensive drums, barrels, cans and containers.

As far back as 1939, the du Pont Co. arranged to get a number of petroleum products from the West Coast to the East Coast by tanker. A little later, Dow Chemical Co. and Carbide & Carbon Chemicals Co. converted tankers for moving caustic soda, ethylene glycol, carbon tetrachloride, ethylene dichloride, propylene glycol and other products. Today, Celanese Corp. of America, the Esso Standard Oil Co., the Oronite Chemical Co. and many others are shipping a large quantity of their products by tanker.

H. S. Hammond is with the MW Protective Coatings Div., Metalweld, Inc., Scotts Lane & Abbottsford Ave., Philadelphia 29, Pa.

Other companies followed this trend of bulk shipments, and built huge tanks in ships and barges for moving hydrochloric acid, caustic soda, formaldehyde, petroleum solvents, glycerine and other products. In each instance where bulk shipments are made by tanker, barge, tank car or trailer—the manufacturer must solve the problem of a suitable lining to protect the product from contamination, and often to protect the steel tank from corrosion.

Metallizing has played an important role in this new trend in shipments. Today, cargo spaces in tankers, large barge-tanks, tank cars and trailers are lined with sprayed metallic zinc, aluminum and other metals to protect the products from contamination and from discoloration.

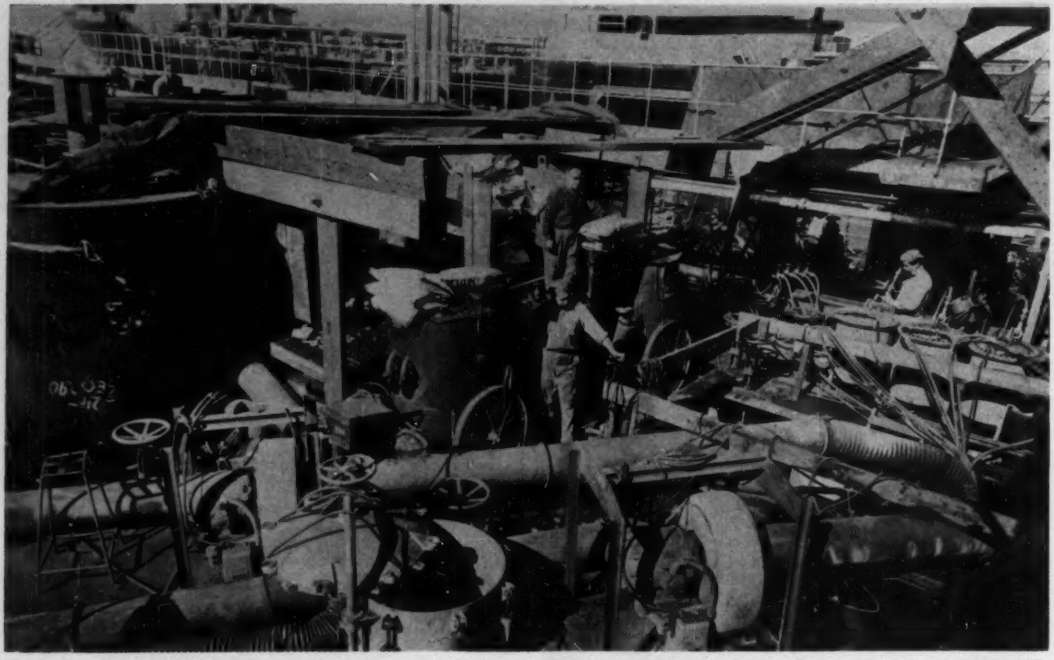
For Solvents, Glycerine

About eight years ago, a large chemical firm began seeking a lining or coating that could be applied to the interior surfaces of cargo spaces in tankers, barges, and large storage tanks—that would be suitable for transporting and storing water-white petroleum solvents, glycerine and similar products.

The requirements were that the coating would have to withstand the solvents without deterioration, and protect them against contamination and discoloration. At the same time, the coating would have to protect the steel against corrosion when tanks were empty on the return trip, and when they were cleaned and degassed for inspection and repair work.

Since there was no organic coating or lining that could be applied in tankers that would fulfill these particular requirements, we recommended either sprayed zinc or aluminum applied by the metallizing process over a thoroughly-sandblasted surface. After thorough laboratory tests, it was found that either of these metals was satisfactory for protecting the products from contamination, and the steel from corrosion. Since the zinc was easier to spray and would give greater cathodic protection to the steel, this metal was chosen.

First job selected for sprayed



JUNKMAN'S DELIGHT shows maze of sandblast equipment, ventilators, piping, hoses, etc. for tanker job.

zinc was in 1949, in one of the tanks of a T2 tanker. Principal products to be hauled were acetone, methyl ethyl ketone, isopropyl alcohol and glycerine—all of which were required to be water-white at destination.

Metallizing Procedure

To prepare the steel surface for zinc spraying, it was necessary to sandblast with a clean sharp abrasive to remove all rust and scale, and to roughen the surface so that the zinc would have a good tight bond to the steel. Several grades of silica sand were available at the job site. However, these were found to be soft and lacked the sharpness required, so that Joplin Grit was selected as the best and most economical abrasive that could be used at the location.

After alterations were made in the tank, separate piping installed to pump the material, and the tank tested for leaks—we proceeded to blast with the Joplin Grit and apply a zinc coating 0.008 in. in thickness by means of the metallizing process. Before starting the work, we had a portion of one of the deck plates removed to provide sufficient area for ventilating pipes, and to remove the abrasive after blasting.

Ventilation equipment was set up, and ducts were arranged as close to the blasters and sprayers as possible. The shipyard furnished tubular scaffolding in the tank—and other facilities such as compressed air for blasting and spraying, power for operating exhausters, and lighting current for dustproof extension lights.

It was decided to blast and spray the bottom of the tank first. This necessitated a period of blasting, followed by a cleaning crew to remove and shift sand between the stiffeners; then a crew of metal sprayers to spray the area completely before there was any chance of oxide forming on the surface.

This procedure was followed until the entire bottom was completed. In spraying the side walls and top, the blasters were followed immediately by the metal sprayers—with no attempt to clean out sand from the bottom between the two operations. Sand was removed periodically as the job progressed by a third shift.

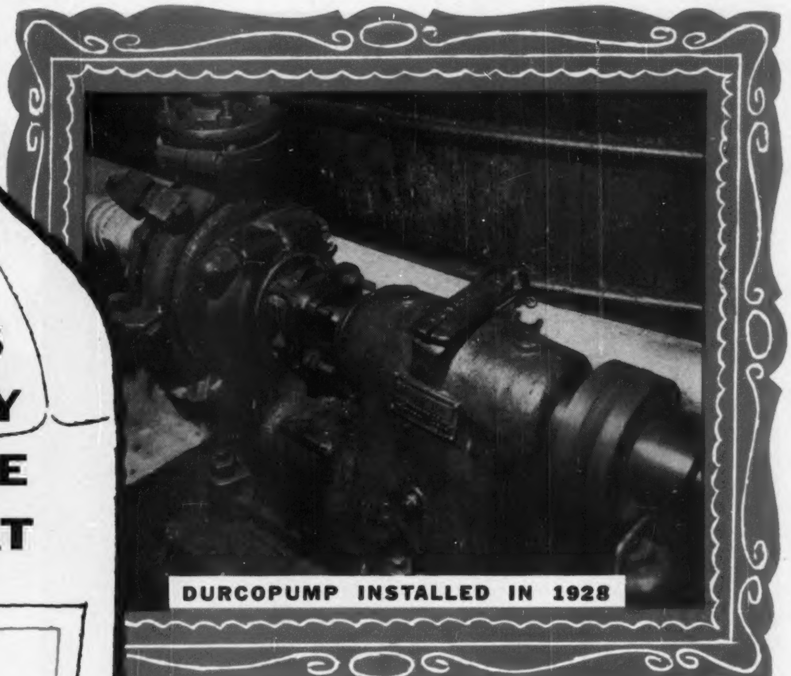
After the zinc spraying was completed, the deck plate was welded in position and the welds were blasted and zinc coated. Areas in the way of scaffold supports were also blasted and touched up with zinc spray. The tank was then thoroughly cleaned of all sand and zinc dust, and washed with fresh water.

During the zinc spraying process, an accurate check was made after each shift to determine thoroughly the thickness of the zinc deposit. This was done by using a magnetic thickness gage. Minimum thickness of zinc allowed was 0.008 in.

During the progress of the work, each sandblaster, metal sprayer and inspector was provided with a gas mask fed with compressed air through a special air filter. A positive pressure was maintained at all times on the gas mask, so that there was no danger of breathing air that was contaminated with dust from the blasting and zinc spraying.

The men were also supplied with rubber hoods that extended over the head and shoulders to keep dust away from the hair, ears and skin. Ventilating fans

DURCOPUMPS



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Vinegar!

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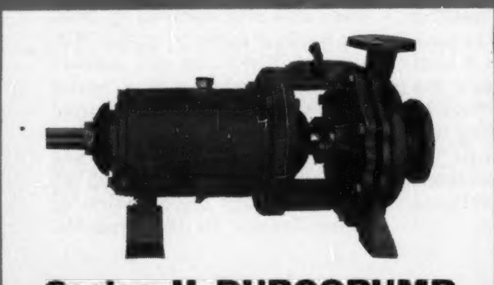

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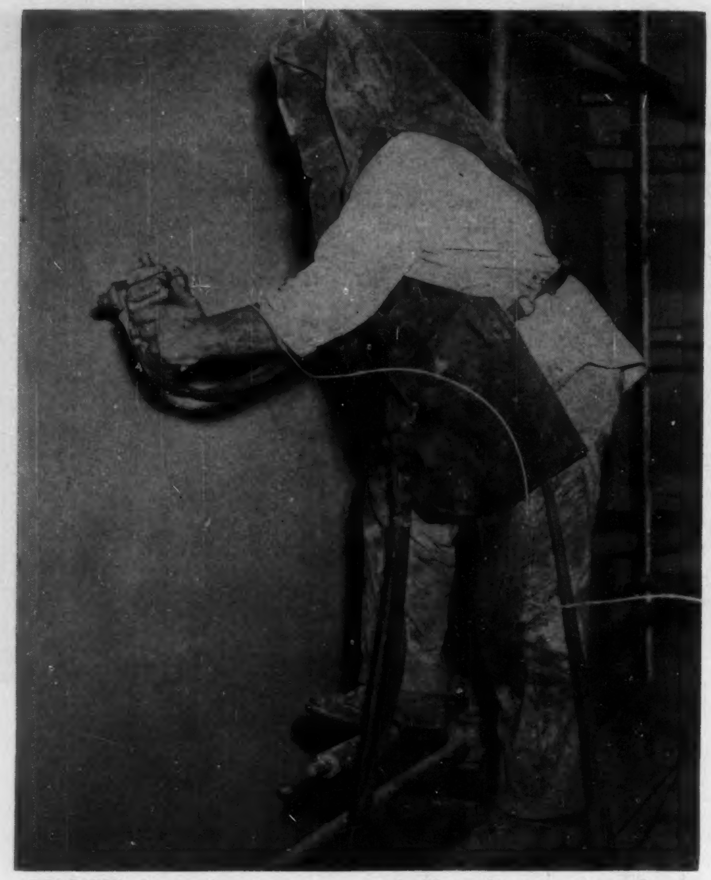


APPLYING zinc coating to cargo spaces inside tanker to protect solvents.

were used constantly while work was in progress and the dust was exhausted over the side of the ship.

After a year's service, the zinc-coated tank was cleaned by a modified Butterworth system, using fresh water. Temperature was held to about 130 F., so that the zinc would not be damaged by high-temperature steam or hot water. After a thorough inspection, it was found that the zinc was protecting over 99% of the surface. Only indication of rust occurred in a few isolated spots that had been missed or poorly-coated in inaccessible places. These areas were touched up by blasting and respraying with zinc.

Repairs and Inspection

During the annual inspection in 1953, it was necessary to make some welding repairs in the tank. There was some question in the minds of the tanker owners whether these repairs could be made while the tanker was in port for a limited time.

As soon as the tank was gas-freed and washed out with fresh water, we sent a two-man crew with a small blast machine and spraying equipment to the site. Then we proceeded to blast and spray the areas that were welded, and had no difficulty in completing the work in the time scheduled. We also made a complete inspection of the tank and found the zinc coating in nearly-perfect condition.

There was some other welding and repair work done in the tank in 1953 in Houston, Tex. A local firm was called in to repair the zinc coating after the repairs were made. The zinc coating was in excellent condition, with no rusty areas that would contaminate the products or deteriorate the steel.

In 1954, another thorough inspection was made over the entire area using a magnetic thickness gage. Lowest readings showed from 0.005 to 0.007 in. thickness, which indicated that the original coating of a minimum 0.008 in. thickness would be good for over a 20-yr. period.

Further Experience

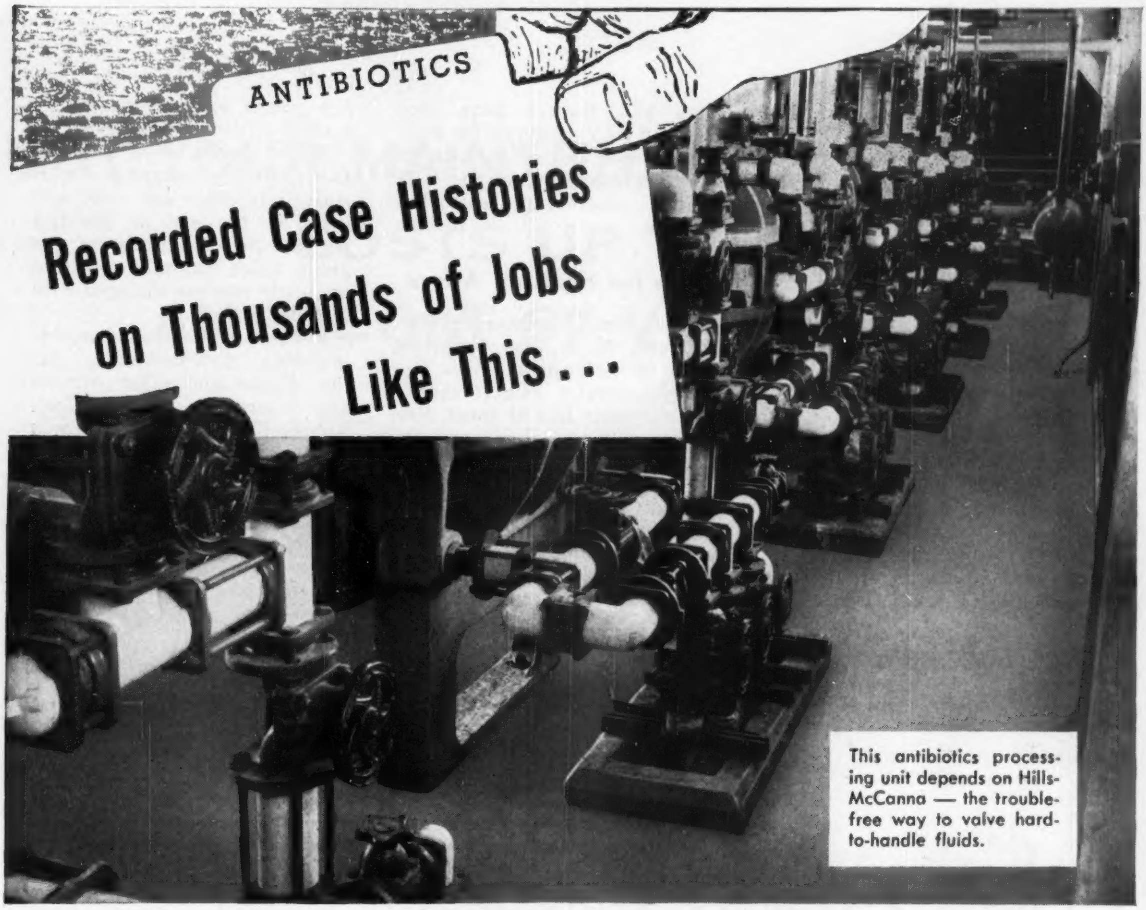
In 1950, the same chemical company decided to have four large tanks (15 ft. dia. × 46 ft. long) zinc sprayed in two barges that operate on the Mississippi River, hauling solvents to Chicago. Same general procedure and technique were used as in the tanker and the work was completed in 1951.

In 1953, the tanker operators were convinced that the use of sprayed metallic zinc was the answer to their problems of shipping solvents free of contamination and discoloration. Therefore, when it was necessary to build a new tanker to handle the increased demand for the contamination-free products, specifications were written to metallize five tanks in the new ship.

The work was to be performed during the construction of the vessel. It was the desire of the shipbuilder and the owner that the delivery date not be delayed due to the metallizing. The entire five tanks, with an area of 61,000 sq. ft., were completed in five weeks. About 300 tons of abrasive was used for blasting, and 29,000 lb. of zinc sprayed to maintain a minimum thickness of 0.008 in. Average thickness was 0.010 in.

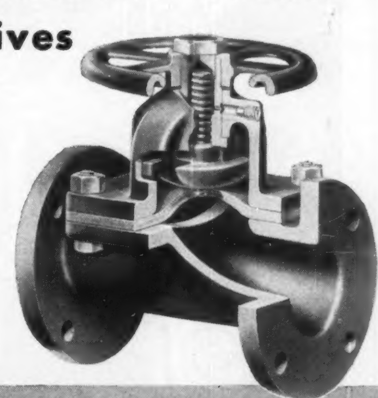
An inspection of these tanks was made in the summer of 1954. Except for a few areas that were missed during the spraying, the entire surface was rust-free and no deterioration of the coating was noticed. The damaged areas were touched up and the ship put back in service.

Four other large barge-tanks were also zinc sprayed in 1953, for hauling solvents on the Mississippi River. In all, tankers and barge-tanks totaling nearly 100,000 sq. ft. have been sprayed with zinc for this one chemical concern for hauling solvents and glycerine. There have been no reports of any discoloration or contamination to the products,



This antibiotics processing unit depends on Hills-McCanna — the trouble-free way to valve hard-to-handle fluids.

Provide the *Know-How* That Saves You Trouble and Expense in Valving Corrosives



The sum total of twenty years experience in valving virtually every conceivable corrosive substance is recorded in the application service records of Hills-McCanna. Here is proved on-the-job data on how to handle over 1000 corrosives . . . specific information on the best diaphragm materials and the best body and pipe materials. For you it means materials recommendations based on facts—not guesswork.

Put this know-how to work for you on your corrosion resistant valving problems by submitting these problems to Hills-McCanna. In Hills-McCanna valves you are offered a choice of 36 bonnet assemblies, 14 diaphragm materials and 27 body materials—a total of 9,121 ways to valve corrosives. To have full information at hand, ask for the Hills-McCanna valve catalog.

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Manufacturers of: Saunders Patent Diaphragm Valves • Chemical Metering and Proportioning Pumps • Force Feed Lubricators • Light Alloy Castings

or corrosion of the zinc-lined tanks.

During the summer of 1955, we completed the zinc spraying of two large storage tanks (60 ft. diam. × 36 ft. high, with an area of 24,000 sq. ft.) in an eastern terminal located near New York. The tanks are for the storage of glycerine. One of the zinc-sprayed tanks in the T2 tanker will be used to haul glycerine from Texas to the eastern terminal.

As far back as 1933, tank cars and trailer-tanks were lined with zinc for hauling glycerine and solvents, and with aluminum for hauling transparent lacquers. Since then, a great many tank cars have been lined for similar service. In recent years, tank cars and trailers have been sprayed with aluminum for hauling phthalic anhydride, with tin for ethylene diamine, and with stainless steel for ethylene oxide.

Tests for Shafting Alloys

The Eco Engineering Co., Newark, N. J., has conducted tests to determine which materials promise longest service life for their line of small, low-volume pumps for corrosive applications.

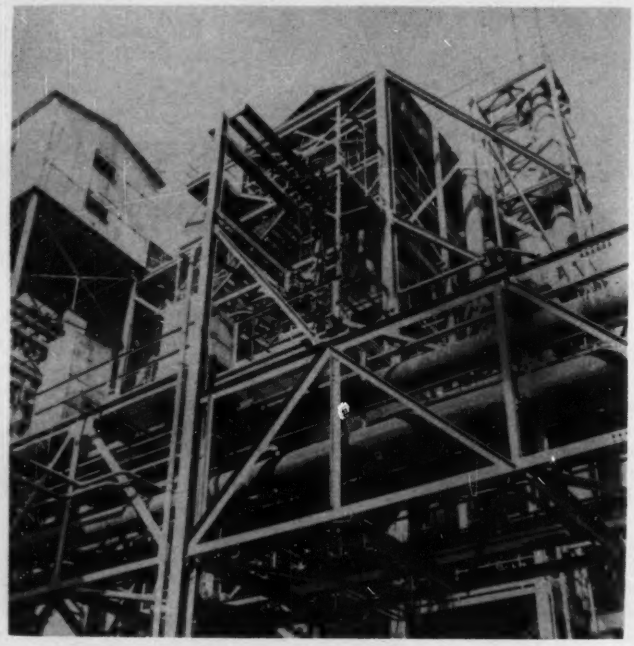
To check the performance of various alloys in parts exposed to wear and stress, they obtained samples of every alloy commonly used for pump shafting. Then they set up a row of standard Eco pumps, each equipped with a shaft of different material.

These pumps were operated for 1,000 hr., pumping a corrosive mixture of salt water and grit. At the end of the test period, the only pump of the group which was still operating efficiently was one equipped with a Monel shaft.

For pumping corrosive liquids including chlorine-bearing fluids, alkalis and other organic and inorganic fluids, Eco's Rubber-Chem pump employs a precision-molded synthetic rubber casing and Monel shaft, separator, guides and eccentrics. It is a positive displacement type with two axially oscillating impellers. Rate of delivery is said to be constant and capacity (up to 10 gpm.) directly related to speed.

According to Eco, this nickel-copper alloy was adopted as standard for this application—not only because it resists corrosion by many chemical fluids but also because it is easily machined, takes a high polish which reduces frictional wear of the shaft and prevents galling and seizing on pump packing.

The alloy also reduces atmospheric pitting which might otherwise affect shafts in intermittent service, and behaves well under the fatigue flex imposed on the shaft by eccentrically rotating impellers.



Industrial Scenario: "Zinc Controls Corrosion"

Galvanized structures are widely used in industrial construction as in this chemical processing plant for the protection they afford against corrosive atmospheres. This is a scene from The American Zinc Institute's new film "Zinc Controls Corrosion," a 35 min., 16 mm. sound and color motion picture. The new film is available to interested groups at no charge. Booking forms can be had by writing The American Zinc Institute, Inc., 60 East 42nd St., New York 17, N. Y.

Handling of PVC Materials

H. N. Hartwell & Son, Inc., Boston, and Bolta Products, A Division of The General Tire & Rubber Co., have established the Plastic Fabricating Institute at Lawrence, Mass.

The Institute was established to train fabricators, distributors, piping contractors and industry in the application, fabrication, welding and forming of unplasticized polyvinyl chloride materials. Special sessions are also being conducted on the proper methods and various techniques in the installation of PVC pipe.

For further information, write directly to H. N. Hartwell & Son, Inc., Park Square Bldg., Boston 16, Mass.

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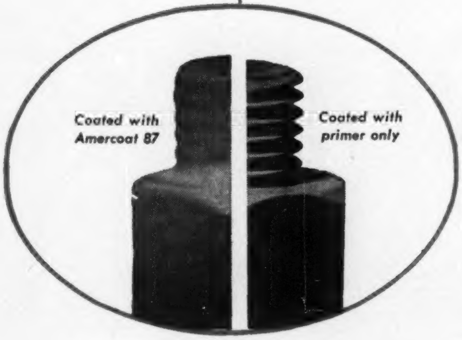

Amercoat 87's thixotropic characteristic helps provide extra thickness on sharp edges and irregular surfaces; it is non-porous and will not crack or check.

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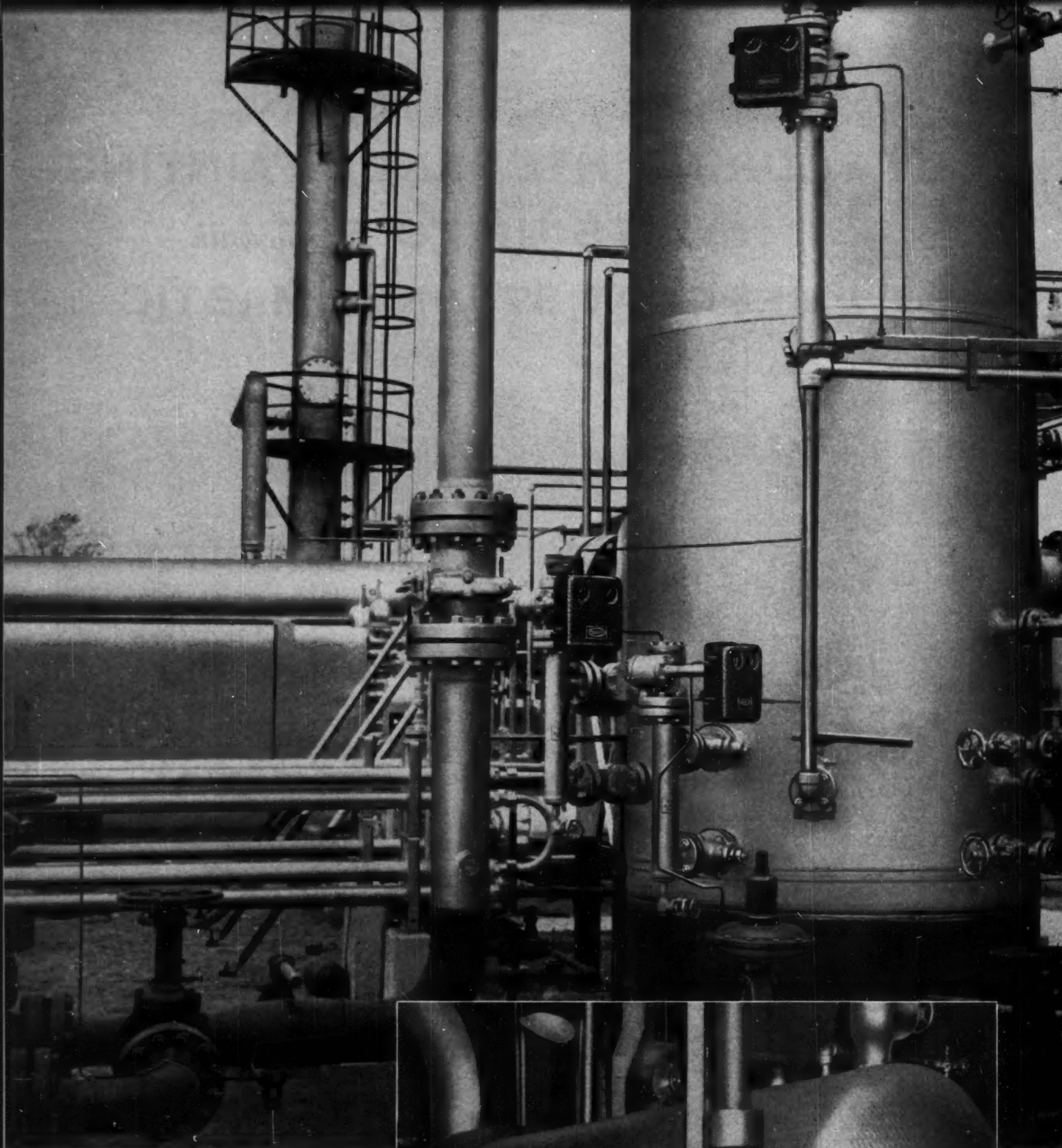
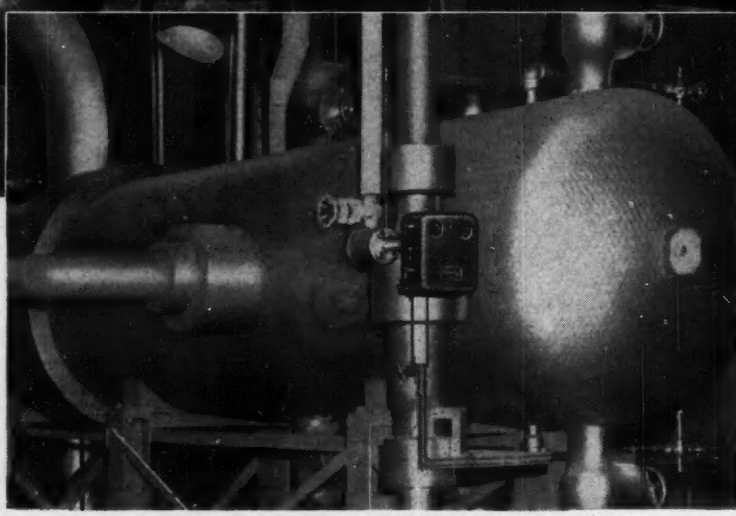
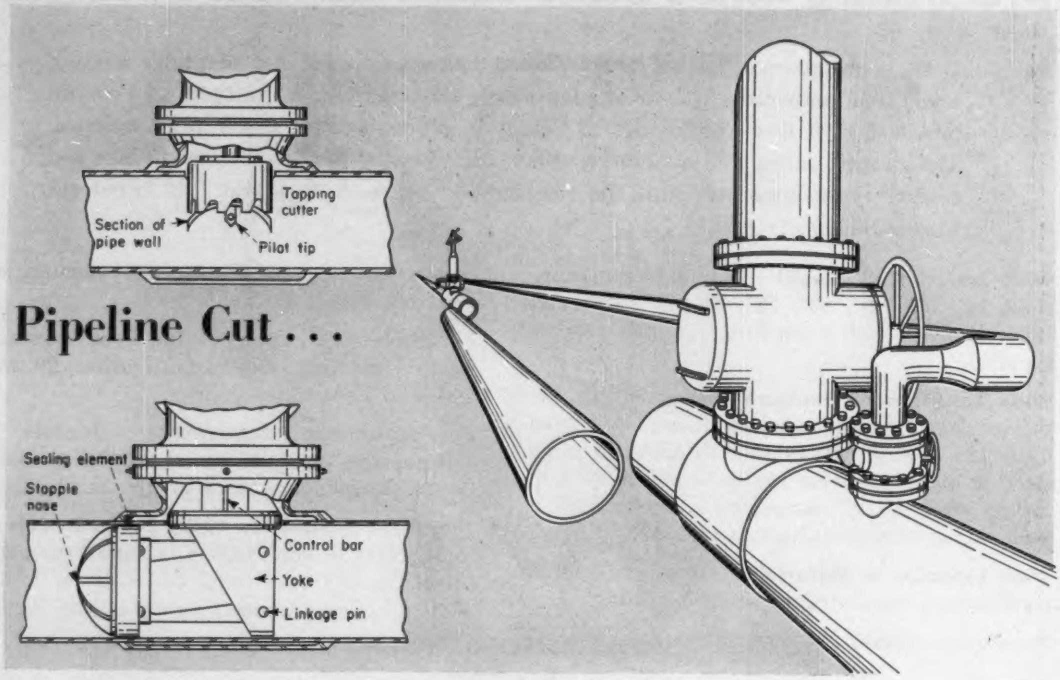


These Masoneilan 12000 Series Liquid Level Controllers are being used for normal and interface level control on a gas dehydration unit.



This is one of the versatile 12000 Series Liquid Level Controllers on a heat exchanger in a power plant installation.



Stopple Set—Flow Diverted—No Shutdown

With stopple device you can cut into main line, divert flow through temporary bypass without shutdown. Processes can be modified without production loss.

Promise of a real boon to plant operating people is offered by the stopple device. For it enables desired modifications to be carried out on operating processes without incurring the penalty of lost production.

Operators of cross-country pipelines already have found that the stopple can make equipment tie-ins possible without costly shut-down. And chemical plant engineers find it fits a real need within the plant (see p. 128).

▶**What It Does**—The stopple equipment and technique introduce a plug into an operating pipeline through a hole tapped in the pipe wall. System pressure seals the plug in the line to stop flow completely beyond that point.

Actually, stopples are used in pairs. One stopple is used upstream and the other downstream of the section of pipeline to be worked on. A bypass carries system flow around the stoppled-off section. Once the stopples are in place, liquid in the isolated section is withdrawn through another tap before proceeding with the work.

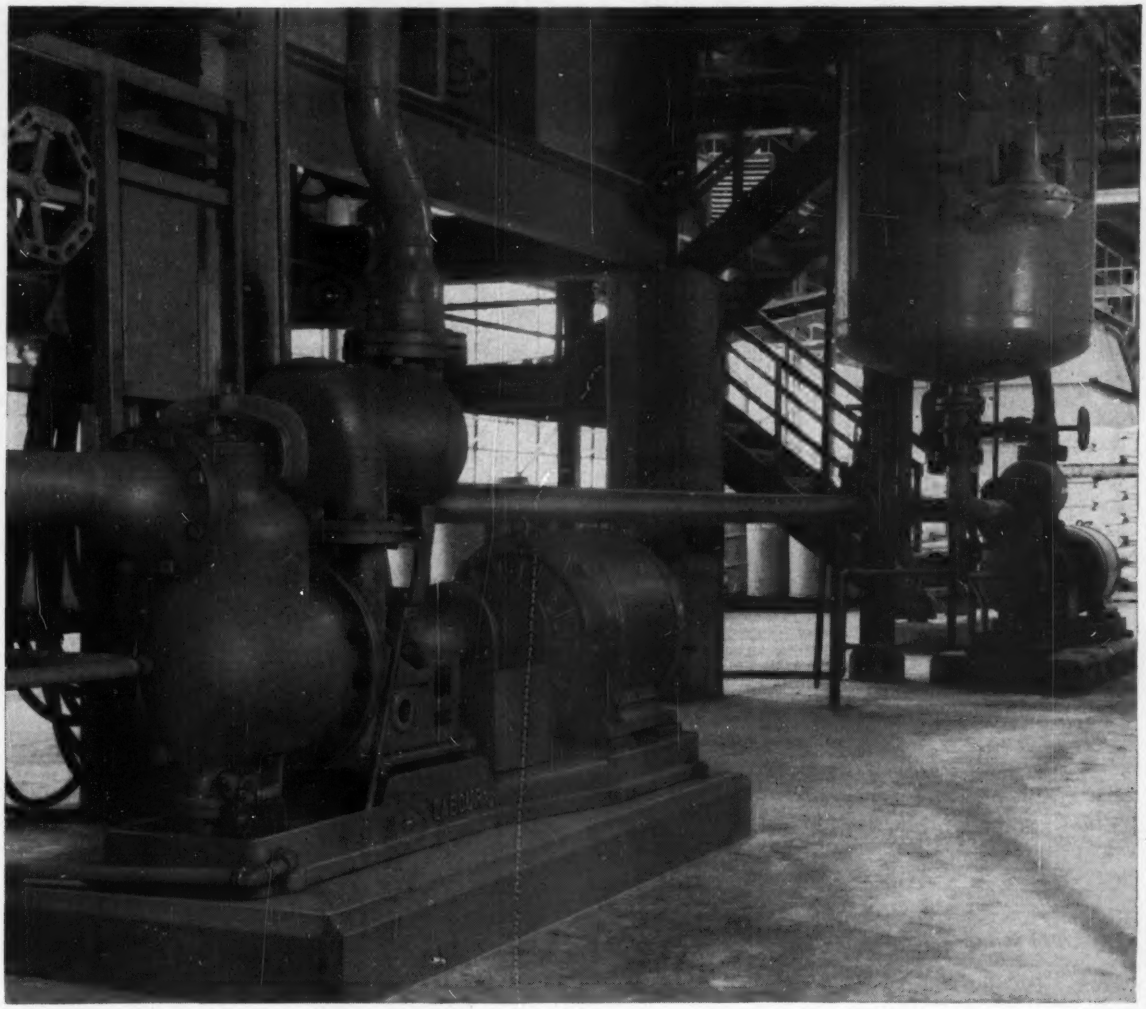
▶**How It Does It**—After isolating a section of the pipeline via the bypass the stopples are ready to be installed. Tapping machine, mounted on a gate valve secured to a Lock-O-Ring flanged-tee fitting, cuts the pipe hole. Gate valve then seals new opening while tapping machine is removed and stopple housing mounted in its place.

Actual plugging portion of the stopple consists of a two-part pyramid-shaped assembly. The nose leads the assembly into the pipe. And the sealing element, the base of the pyramid, provides the seal.

Hard leading edge of the sealing assembly gives the structural strength to the seal to withstand high pressures. The trailing edge, on the other hand, is of soft neoprene so that it lips against even the roughest-surface pipe wall with a positive, leakproof seal.

The total assembly is linked to a yoke which is an extension of the stopple control bar. By revolving the insertion crank at the top of the stopple the control bar can be raised or lowered.

At the time of installation the control bar is raised. By cranking it down, the yoke is lowered



What are LaBour pumps doing at Eli Lilly?

That's simple . . . they needed top *performance* and *dependability* so they chose LaBour.

The LaBour pumps shown above are handling an aqueous solution of antibiotic from fermentation to purification . . . pumping from vacuum filters under 25" of mercury. The problem was not one of corrosion, but of *performance* and *dependability*. That's why the pumps are LaBours.

This plant, the Eli Lilly Tippecanoe Laboratories at Lafayette, Indiana, was recently designated as the "SIGNIFICANT PLANT" of the year 1955. This award was made because of the consideration given to the selection of equipment . . . the dependability of that equipment to perform day-in, day-out with minimum down time.

LaBour pumps are known for their pumping ability in handling both air and liquids. Each LaBour pump is backed by more than 30 years of intimate contact with the problems of process industries. If you need a top *performing, dependable* pump — to work under vacuum or with flooded suction, to handle corrosive or non-corrosive liquids — you can't do better than LaBour. It's the pump the experts select!

ORIGINAL MANUFACTURERS OF THE SELF-PRIMING CENTRIFUGAL PUMP

LaBOUR

THE LaBOUR COMPANY, INC. • Elkhart, Indiana, U.S.A.

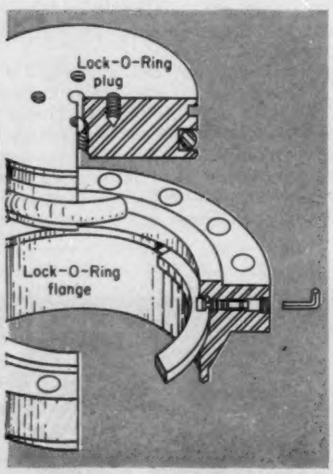
Newsworthy Equipment This Month

through the open gate valve and Lock-O-Ring flanged fitting into the pipe tap. When it reaches the bottom of the pipe the links pivot on their pins and the hinged assembly changes its vertical descent for a horizontal entrance into the pipe. Fluid pressure seats it snugly and the flow is cut off.

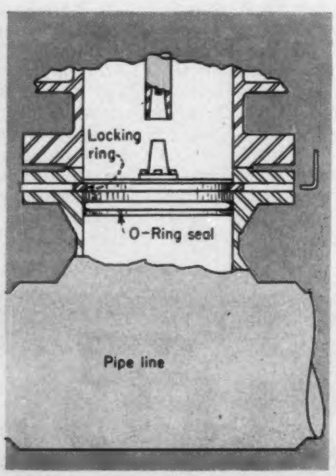
▶ **Return to Normal**—Once modifications are completed and the revamped system has been connected back into the line pressure is equalized and, the stopples are removed. Lock-O-Ring plugs are lowered into the Lock-O-Ring flange by the tapping machine to seal off the tap. The gate valve then can be recovered and re-used.

The plug is a disk with a ring segment groove running around its circumference. A neoprene O-ring runs around the plug just below this groove. The tapping tool holds the plug by a conical plug holder fastened to the plug with four bolts. After the plug is in place this holder can be removed and a blind flange placed over the Lock-O-Ring flange.

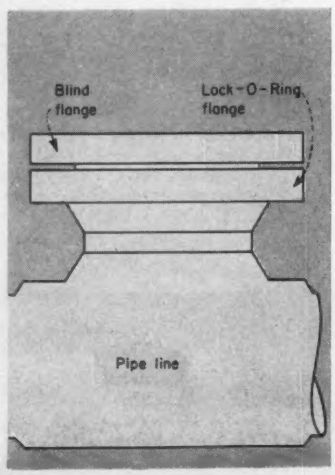
When the plug is in place four steel segments, recessed around the flange's inner circumference, are advanced by set screws so that they seat in the matching groove on the plug. These hold the plug against the line pres-



VIEW of flange and plug.



PLUG in place for tight seal.



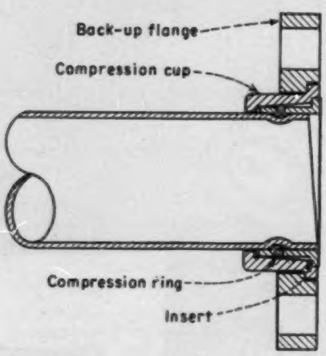
AND the valve is salvaged.

sure. And the O-ring on the plug completes the seal.

The Lock-O-Ring plug and flange combination is used on the bypass taps as well. Consequently the gate valves on that part of the piping can be salvaged after the piping modification is completed.

▶ **Working Limits**—Stopples are reported to work well over pressure ranges from 8 oz. to 1,700 psi. at temperatures up to 440 F. They are effective on liquids and gases such as crude oil, propane, nitrogen, chemicals, steam.

Equipment is available on a rental basis for the occasional user, as well as on outright purchase.—**T. D. Wiliamson, Inc., P. O. Box 4038, Tulsa 9, Okla.** 290C



Pipe Flange

Installs without special tools.

Newly developed for the chemical processing industry is a flange for use with Schedules 5 and 10 pipe. Only a blank flange and the usual bolts are needed to compress the assembly into a finished Van Stone type fitting.

Elements of the complete unit are a back-up flange, a compression cup, a rubber or Teflon O-ring, an insert ring and a compression ring.

To make up, you slip the back-up flange over the end of the pipe, followed by the compression cup and O-ring. The insert and compression ring assembly is placed in the proper position so it is flush with the end of pipe.

Next, compression cup is seated in back-up flange and pulled up over the insert. Final seating of insert in compression cup is done by drawing the parts together with bolts against a blank flange.—**Star Tank & Filter Corp., 875 Edgewater Rd., New York 59, N. Y.** 292A

Impact Fitting

Assures long life and low friction loss.

Body of the fitting is cast from a hard, chrome-iron alloy — Ashcolite — which provides top wear resistance, long life. And the elongated discharge end cuts pipe connection eddies created by sharp turns thus reducing friction loss in pneumatic materials handling systems.

A separate, reversible wear-back, cast from an especially hard alloy (Ni-Hard) is bolted to the body via slotted lugs. This feature, making easy replacement or reversing of the wear-back possible, distributes the wear over the fitting.

Complete line is cast with plain ends to simplify installation. However adaptors are available for connection to flanged pipes. Line includes 45- and 90-deg. elbows and 45-deg. lateral fittings in 4, 5, 6, and 8 in. sizes. Wear-backs are interchangeable with all fittings of a given size.—**The Allen-Sherman-Hoff Co., 259 East Lancaster Ave., Wynnewood, Pa.** 292B

Globe Valve

Aimed at high pressure needs.

A new line of bronze globe valves, rated at 200 psi. steam pressure and at 400 psi. water, oil and gas pressure, claims to fill the bill for a higher-pressure, throttling valve.

Body and bonnet of the valve are constructed from S-1 Bronze —called the highest-grade valve bronze ever formulated. An extremely close-grained material it features high density, strength, top wear and corrosion resistance.

Boosting further the toughness of this fitting are the Brinalloy seats and disks used. This material boasts greater resistance to wear and corrosion than 1000 Brinell case-hardened stainless steel.

Five years of industry-wide throttling-service tests without a single failure indicate that the combination of these materials provide a long-life globe valve—**Lunkenheimer Co., Cincinnati, Ohio.** 292C

Centrifugal Pump

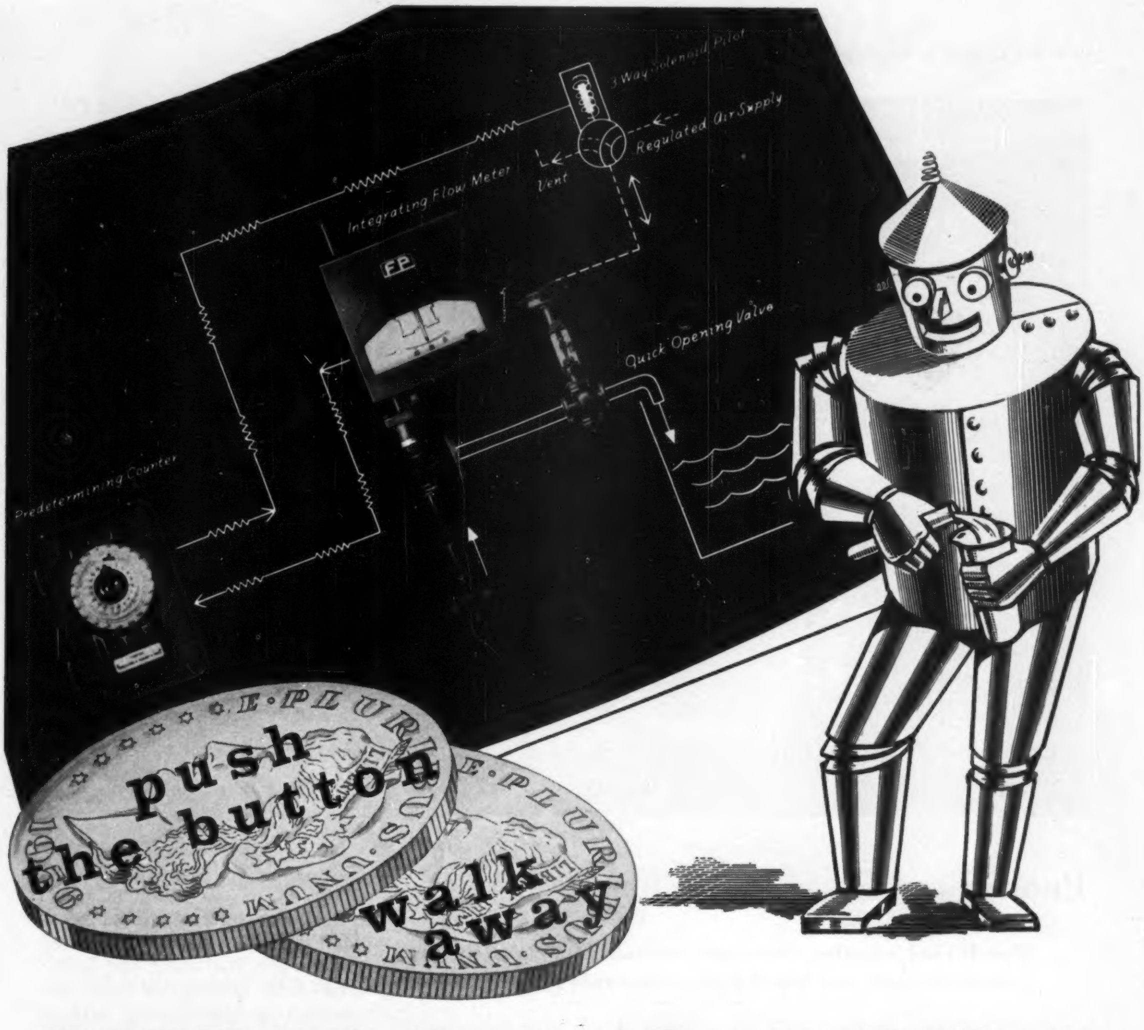
Interchangeable parts make one pump into seven.

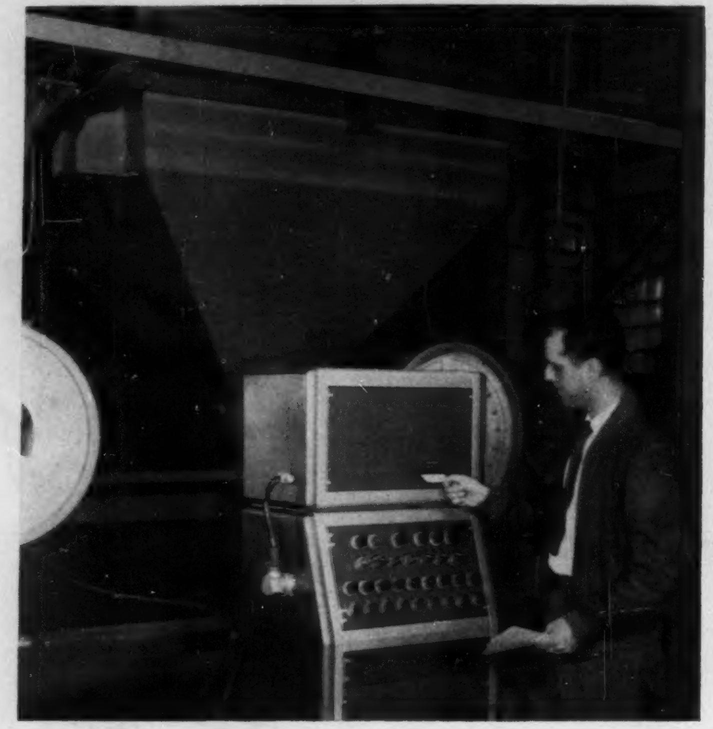
Every part except three of a new line of seven standard centrifugal pumps are interchangeable. The three parts—impeller, casing and back head cradle—vary the size and the capacity of the seven pumps. A single cradle combination assembly converts any one of the seven pumps to any other one as long as two size back head cradles, seven casings and seven impellers are stocked.

Size and capacity of the line range from 1 by 2 in. to 3 by 4 in. suction and discharge nozzle diameters delivering up to 600 gpm, against heads of up to 275 ft. Aimed at general and chemical service when a highly engineered unit is not required the pumps offer minimum spare parts inventory and storage space, low maintenance cost. Pumping temperature range is from −40 F. to +350 F.—**Dean Bros. Pumps Inc., 323 W. 10th St., Indianapolis, Ind.** 292D

For More Information...

about any item in this department, circle its code number on the Reader Service Postcard inside the back cover.


3 Way Solenoid Pilot
Regulated Air Supply
Vent
Integrating Flow Meter
FP
Quick Opening Valve
Predetermining Counter
push
the button
walk
away



Punch Card Governs Batching

Punch card actuates electronic controls in weigh batching system to select and weigh precise amounts of components.

A new electronic weigh batching system works in conjunction with IBM's punch card system. For the first time, it is reported, the speed and accuracy of electronics have been united with commercially acceptable weighing units.

With the Helco-matic Batchmaster system, combinations of material weights and selections are unlimited and can be changed instantaneously. Where repetitive batches are called for, the Helco-matic will cycle automatically.

System is fully interlocked and meets all existing Federal and State specifications. There are no limiting features that could confine application of the system to any particular field.

▶ **Compact Enclosure** — Control unit is housed in a compact console, no larger than a standard filing cabinet. It can be located either close to the weighing equipment or at a more remote spot.

The Helco-matic has a controlled closed circuit that practically eliminates the possibility of malfunctioning due to vibration, moisture or dust. Pushbuttons are provided for all controls so that individual materials can be batched manually.

▶ **Moisture Compensator** — A moisture compensating feature eliminates the problem of compensating for moisture by weight. After the operator sets moisture content on the control dial, the machine automatically adjusts proportions of dry material and water to correct for a change in moisture content of the dry constituent.

With an eye to easy maintenance, the designers of Helcomatic have grouped all major components of the machine on individual drawers. These can be removed quickly, or mounted on panels that swing into position for easy repairing.

▶ **From Start to Finish**—Punch card for a given batch is made up in standard fashion. Pertinent information regarding identification and weights of materials are entered on the card. These figures are converted to the necessary perforations by a simple key punch operation.

Perforations indicate which gates or valves will be opened and the amount of material to flow through each control point. The finished card becomes a permanent record of the operation.

Manufacturer of this equipment indicates the Helco-matic system is well suited to batching chemicals, fertilizers, refractories and food components. — **The Heltzel Steel Form & Iron Co., Warren, Ohio.** **294A**

Rotary Feeder

Built with integral, variable speed.

A rotary feeder that incorporates an integral, variable-speed drive is reported well suited for bulk chemical service. Unit has been well tested on the job, including one handling hot, abrasive chemicals containing hydrofluoric acid at 10 psi.

The variable-speed drives can be equipped with speed indicators and remote controls, if needed.

Two models are available—one for $\pm 3\frac{1}{2}$ psi. and the other for pressure to 10 psi. Special constructions of the higher-pressure model have been made for service on material up to 800 F.

Available sizes are 4, 6, 8, 10 and 12 in.—**Beaumont Birch Co., 1505 Race St., Philadelphia, Pa.** **294B**

Package Assembly

Pneumatic unloading for small and medium needs.

A new package assembly of a pneumatic unloading system makes it possible for medium and small size plants to reap

the advantages of pneumatics. Named "Airo-Flow" the assembly consists of a 25 hp. motor, a rotary positive displacement blower, a cyclone separator, blow-through air lock, inlet nozzle, flexible hose and auxiliary piping and fittings for a complete package.

An unloading rate of six to eight tons/hr. of light material and 10 to 15 tons/hr. of heavier materials is claimed for the system. These figures assume a vertical lift and horizontal run of from 75 to 100 ft. with no more than two 90 deg. turns. The assembly can be adopted for straight line conveying as well.—**Sprout, Waldron & Co., Muncy, Pa.** 294C

Solids Pump

Fluidizes solids and moves them like water.

Handling a remarkable variety of solids this Fluidizer solids pump moves them with the ease of conventional pumps moving liquids. Portable and easy to install without expensive plant modifications, the unit is commercially pumping solids from alfalfa meal to zinc oxide.

Example of the pump in action; with a power consumption of three horsepower and a solids to air ratio of 125 to 1, flour was conveyed through a 1$\frac{3}{16}$ in. inside diameter tube a distance of 25 ft. at the rate of 100 lb./min.

Immediate applications for the pump are unloading and loading of bulk trucks and railroad cars, conveying of material from bins to packing operations. And all these operations are accomplished without dusting.—**Superior Separator Co., Hopkins, Minn.** 296A

Fork Trucks

Newest type since war.

A new line of fork trucks features a raft of advanced innovations corresponding to progressive automotive trends. Among the improvements; a 12-v. electrical system, fully automatic transmission, emergency fuel tanks, foam rubber seats and automobile type controls. Touted as exclusive features are the truck's self-adjusting brakes, combination of lift-tilt controls on the steering column and the balanced swing-up hood for easy engine maintenance.

Streamlined through the chassis the line includes gas models with capacities from 2,000 to 5,000 lbs. And electric and gas models with greater capacities will be added shortly. The hydraulic system is rated at 2,000 psi. And the engines have a full-load speed of from eight to 12 miles/hr.—**Industrial Truck Div., Clark Equipment Co., Battle Creek, Mich.** 296B

Portable Platform

Loads rail cars in limited space.

When this portable magnesium platform is used in conjunction with the manufacturer's yard ramp, loading of railroad cars can be accomplished in very limited trackside space. Ordinarily, the yard ramp is positioned at the car door opening when the side space is sufficient. Otherwise the ramp is attached to this new platform parallel to the track and the loading truck rides up it to the platform where it loads the rail car.

The platform is 96 by 96 in. and weighs about 772 lb. It is positioned easily by a fork truck. Platforms' capacities range from 6,000 to 16,000 lb. Adjustable height legs for easy leveling and safety curbs around its deck mark desirable features of the platform.—**Magnesium Co. of America, East Chicago, Ind.** 296C

For More Information...

about any item in this department, circle its code number on the Reader Service

Postcard inside the back cover.

Front End Loader

Large capacity for confined areas.

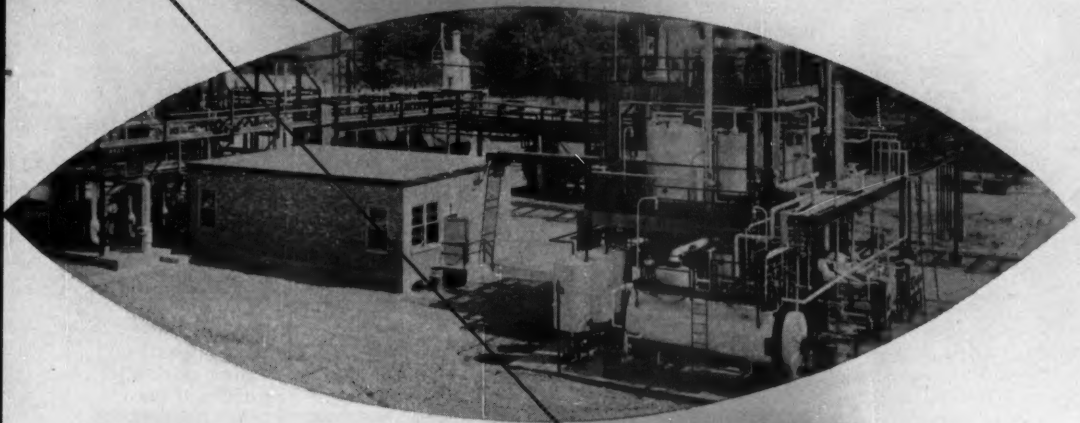
A front-end loader, the TL-11 Tracto-Loader, has been introduced to the bulk handling market. Machine has 1¼ yd. capacity, can operate in confined areas.

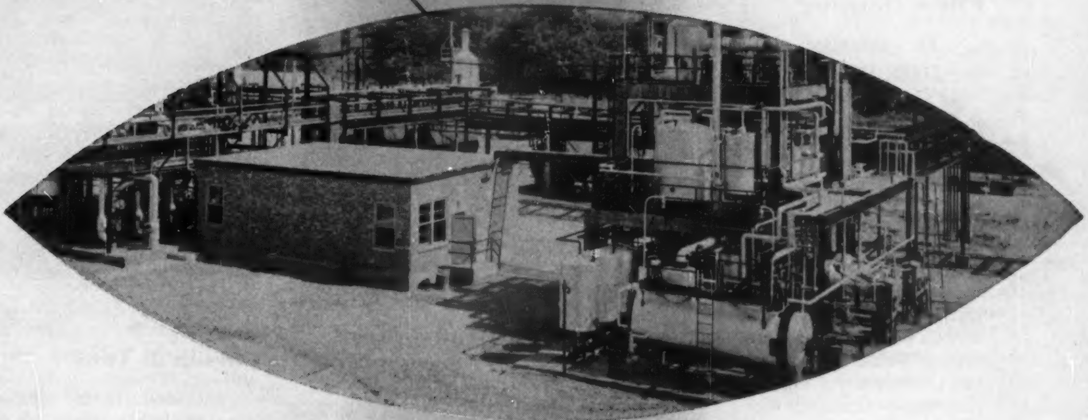
Loader has front-wheel drive for good traction and is equipped with rear-wheel power steering. Choice of power is either a 63 hp., 4-cylinder gasoline engine or a 77 hp., 6-cylinder diesel engine.—**Tractomotive Corp., Deerfield, Ill.** 296D

Equipment Cost Indexes

Industry	Dec. 1955	Mar. 1956
Avg. of all	196.9	201.3
Process Industries		
Cement mfg.	188.8	192.5
Chemical	198.1	201.9
Clay products	183.4	187.0
Glass mfg.	197.1	190.7
Paint mfg.	190.6	194.3
Paper mfg.	190.9	194.6
Petroleum ind.	194.5	198.3
Rubber ind.	197.0	200.8
Process ind. avg.	194.6	198.4
Related Industries		
Elec. power equip.	199.9	203.8
Mining, milling	199.3	203.2
Refrigerating	219.0	224.9
Steam power	186.6	190.2

Compiled quarterly by Marshall and Stevens, Inc. of Ill., Chicago, for 47 different industries. See Chem. Eng., Nov. 1947, pp. 124-6 for method of obtaining index numbers; March 1956, pp. 194-5 for annual averages since 1913.





Filter Housing

For one-man, speedy cartridge replacement.

Containing micronic, full-flow filter cartridges these newly engineered filter housings are aimed specifically at process liquids and high-capacity lube systems on engines and machinery. The long-effective-life cartridges are easily replaced by one operator and the entire unit is maintained with equal ease. By simply dropping the swing bolts the cover can be set aside with a handle and the cartridge changed.

Largest in the series is the filter housing measuring 2½ ft. across the flanges and 4½ ft. high. This unit handles 500 gpm. of clarified liquid with a pressure drop of 2 psi. giving 25 micron filtration. The smallest unit measures 2 ft. by 3½ ft. and handles 80 gpm. flow under the same conditions.—**Cuno Engineering Corp., Meriden, Conn.** 298A

Liquid-Feed Blender

Liquids and solids mix swiftly in single operation.

A single operation is all that this new liquid-feed blender requires to blend swiftly liquid and dry materials. This modification is designed as an integral part of the *p-k* twin-shell blender. Mating a wide variety of, until now, unblendable liquid-solid mixtures this unit should find plenty of uses in the plastic, chemical and food processing industries.

An improved intensifier bar revolves inside a standard twin-shell blender. Liquid droplets, flowing from a hollow feeder tube, fly from the edge of a revolving disk to give an effective dispersion with the dry material. The unit makes it possible, perhaps for the first time, to feed the liquid into the dry materials evenly during the blending operation.—**The Patterson-Kelley Co., Inc., East Stroudsburg, Pa.** 298B

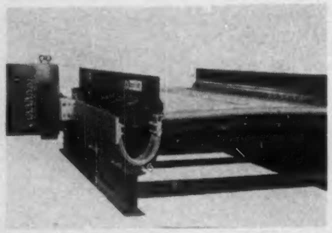
Magnetic Separators

Lab scale reproduces commercial size operation.

Separation of dry, granular, weakly magnetic materials from non-magnetic materials can now be accomplished efficiently on the laboratory scale with this high intensity magnetic separator. The unit will find use in the purification of silica sand, borax, feldspar and other similar products.

Material flows onto a highly magnetized revolving rotor. The magnetic particles cling to the rotor longer than do the non-magnetic to accomplish the separation. Carefully located knife-edge dividers facilitate the operation.

Rotor is mounted on extra-heavy ball-bearing pillows. The motor drives the rotor through a variable-speed drive adjustable from about 80 to 300 rpm. An electromagnetic coil with rheostat control produces the magnetic circuit.—**Exolon Co., 951 East Niagara St., Tonawanda, N. Y.** 298C



Heated Screen

Unsticks sticky stuff.

This heated screen handles damp and sticky materials without blinding or fouling during the screening operation. Clay-handling, agricultural lime production and other chemical process industries will benefit by this development. Current is supplied from a specially designed dust-tight voltage transformer.

The screen has 35 sq. ft. of available screening area constructed from stainless or carbon steel. Fully balanced, the assembly provides a positive high-speed action over the entire deck surface. — **Simplicity Engineering Co., Durand, Mich.** 298D

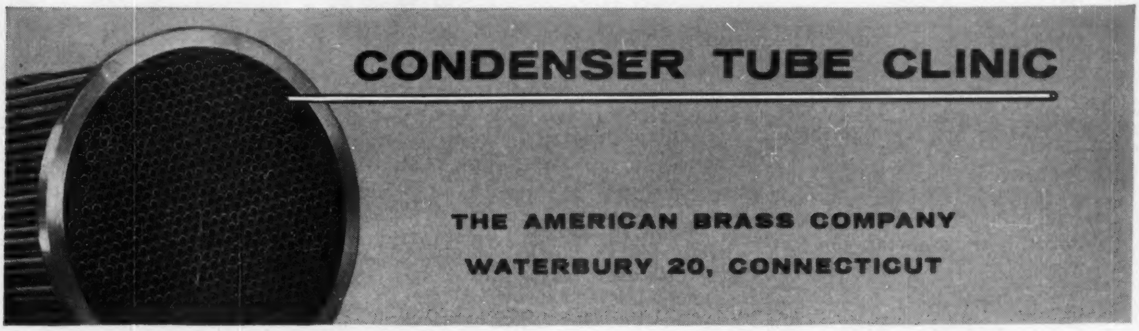
Chemical Tanks

Molded from single, unbreakable piece of plastic.

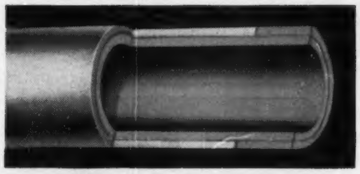
A new line of chemical tanks are molded in one continuous piece from non-breakable polyethylene. Consequently, seams, welds and joints are eliminated from the tank structure. Danger of leaks and corrosion is substantially reduced.

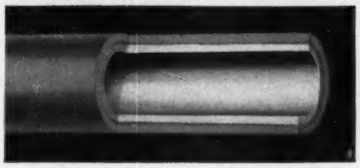
Ranging in sizes from 5 to 160 gal. the line has a multitude of applications. The plastic's extreme resistance to caustics, acids, and even hydrofluoric acid recommends the tanks for mixing, storage, compounding and processing of foods, pharmaceuticals, salts, water softeners and cleaning or plating of metals.

Even the largest of the tanks are completely self-supporting. Cylindrical, cubical and rectangular shapes with covers, at comparatively low costs, are available.—**Delaware Barrel & Drum Co., Inc., P. O. Box 1648, Wilmington, Del.** 298E



How two-tubes-in-one can help you solve complex corrosion problems





Edited by James T. Kemp, Metallurgical Engineer

ANACONDA Duplex Heat Exchanger Tubes are for two types of service—where the corroding characteristics of fluids inside and outside the tube are best met with different metals or alloys—where internal or external pressures, or the pressure-temperature combinations, are too great for a nonferrous tube alone. In the latter case, an Anaconda copper alloy with the required corrosion resistance is placed outside or inside a steel tube—and the pair is drawn together. The finished Duplex Tube has the chemical properties required for the more corrosive fluid handled—plus the needed strength.

TWO SEPARATE CORROSION PROBLEMS. A Duplex Tube of steel with copper or a copper alloy inside is used, for example, in exchangers or condensers handling water in the tubes and ammonia or a fluid with appreciable amounts of ammonia in the shell. Moist ammonia attacks copper and all of its alloys, and may cause stress-corrosion cracking. Stresses may be due to applied loads or may be residual from cold working of the metal. Steel, however, is not susceptible to such action by ammonia. Thus the nonferrous tube is shielded and can perform its normal function of giving long service life and efficient heat transfer on the "water side."

Other combinations of coolant—or heating fluid—and "stream" are found in petroleum refineries and chemical plants, in which differing properties are required inside and outside an exchanger tube. Here two nonferrous metals may be combined—a Cupro Nickel and Admiralty, for example.

HEAT TRANSFER. Duplex Tubes have thermal transfer characteristics somewhere between those of the two metals used. Each face of the tube has the receptivity-emissivity of its metal. The metal-to-metal interface is so intimate it offers little resistance to heat flow.

FERRULES. Duplex Tubes can be supplied with ferrules of the same composition as the inner tube (see upper illustration), replacing a short section cut from the end of the outer tube. This ferrule prevents excess corrosion of the ends exposed in the exchanger channel. The ferrule should be long enough to be securely rolled in when the Duplex Tube is expanded into the tube sheet.

TECHNICAL ASSISTANCE. The American Brass Company's metallurgical engineers and its sales representatives throughout the country are available to help you in the selection of the Anaconda Condenser Tubes to meet your problems. Write: Technical Department, The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5678

ANACONDA®

Tubes and Plates for Condensers and Heat Exchangers

PHYSICAL PROPERTIES OF ANACONDA CONDENSER TUBES*

ALLOY	Tensile Strength, psi	Yield Strength at .5% Elongation Under Load, psi	Elongation in 2", %	Rockwell Hardness, B Scale	Density, Lb. per Cu. In.	Thermal Conductivity, B.T.U./Sq. Ft./In./Hr./°F. at 68° F.	Average Coefficient of Linear Thermal Expansion per °F. (77-572 F.)
Arsenical Admiralty-439	52,000	22,000	60	6-45	0.308	768	.0000112
Ambraloy-927	60,000	27,000	55	35-65	0.301	696	.0000108
Ambraloy-901	60,000	30,000	60	30-60	0.295	552	.0000099
Cupro Nickel, 30%-702	55,000	22,000	50	30-60	0.323	204	.0000090
Cupro-Nickel, 10%-755							
Light Annealed	44,000	22,000	46	25	0.323	314	.0000093
Light Drawn	60,000	57,000	15	68			
Red Brass-24	42,000	15,000	50	0-30	0.316	1104	.0000104
Ambronze-421	46,000	20,000	55	0-30	0.316	830	.0000102
Phosphorized Arsenical Copper-108							
Light Drawn	40,000	35,000	20	20-50	0.323	1344	.0000098
Hard Drawn	54,000	50,000	8	50-70			
Phosphorized Copper-103							
Light Drawn	40,000	35,000	20	20-50	0.323	2364	.0000098
Hard Drawn	54,000	50,000	8	50-70			

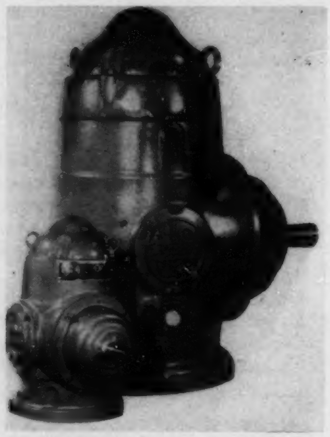
*Note: The above values are approximate and should not be used for specification purposes. *Light annealed except as noted.*

Germanium Rectifier

Offers flexible application.

This new 50 kw. heavy duty germanium rectifier is furnished in a floor standing cabinet for space saving compactness. Since it may be connected either in parallel or series, or parallel and series it is suitable for numerous applications. In these combinations it can provide various direct current voltages and amperages exceeding those of a single unit.

At 400 amp. a single rectifier's d.c. output is from 115 to 125 v. and at 800 amp. is 62.5 v. The over-all dimensions of the compact 1,200 lb. cabinet are 34 in. wide, 30 in. deep and 52 in. high. The rectifier is forced air cooled. — **Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif. 300A**



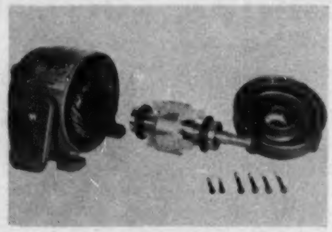
Right-Angle Gear Drive

Line growing bigger and better.

This line of right-angle gear drives has been expanded to include units ranging up to 150 hp. And in extending in the opposite direction it has spawned an eleven horsepower baby.

Universally adaptable to any vertical turbine pump driven by gas, gasoline or diesel engine the drives are available in a wide selection of gear ratios and speeds. Permitting integral mounting of the pump shaft the gear drive assures high efficiency and precise adjustment of pump impellers. A reverse protection clutch prevents pump and drive damage if the engine should accidentally reverse itself.

Heat-treated castings remove internal stresses, prevent distortion. Weatherproof construction of the drive protects against dust and rain. A complete oil system provides total lubrication. — **U. S. Electrical Motors Inc., Box 2058, Terminal Annex, Los Angeles 54, Calif. 300B**



Synchronous Motor

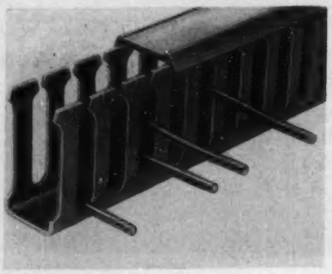
A hybrid, it revs up as induction motor, then rises to synchronous speed.

Combining design features of induction and synchronous motors this hybrid Synduction motor provides advantages of both. It answers the need for a constant speed motor (a synchronous motor characteristic) in sizes below 40 hp. with low first cost, rugged mechanical construction and simplicity of maintenance (induction motor characteristics).

Motor is built on a standard induction motor frame and enclosure using a simple die-cast rotor. Result: It requires no brushes, slip rings or windings on the rotor, no separate source of d.c. excitation or special starting equipment.

Motor starts and accelerates almost exactly as an ordinary induction motor. The rotor is accelerated to a speed just below synchronism. If the load inertia is within design limits the motor speed quickly rises to synchronous speed.

Available in ratings from ¼ to 40 hp. the manufacturer expects to tailor each unit to its particular job. Frequencies of from 10 to 300 cycles are available with speeds to more than 10,000 rpm. — **Allis-Chalmers Mfg. Co., Milwaukee 1, Wis. 300C**



Panel Conduit

Designed to reduce wiring time.

A new type control-panel conduit features an exclusive slot design to reduce wiring time to a minimum.

Wires can be inserted or removed from the conduit merely by snapping in or out of the slot. Design permits lugs to be attached before wire is inserted and allows the wire to be removed with lugs attached.

A new fastener holds both duct and cover to prevent either from slipping. Although it is an internal nut and bolt arrangement, it does not interfere with insertion of the wire.— **Panduit Co., 10132 South Washtenaw Ave., Chicago 43, Ill. 300D**

Explosion-Proof Motors

Aimed at three top hazards.

A complete line of explosion-proof motors meet underwriters' requirements for the three commonest hazard locations; gaseous, explosive dust and explosive grain dust. This means that the motors will not trigger destruction in gasoline refineries, paint and varnish plants, dry cleaning plants etc.

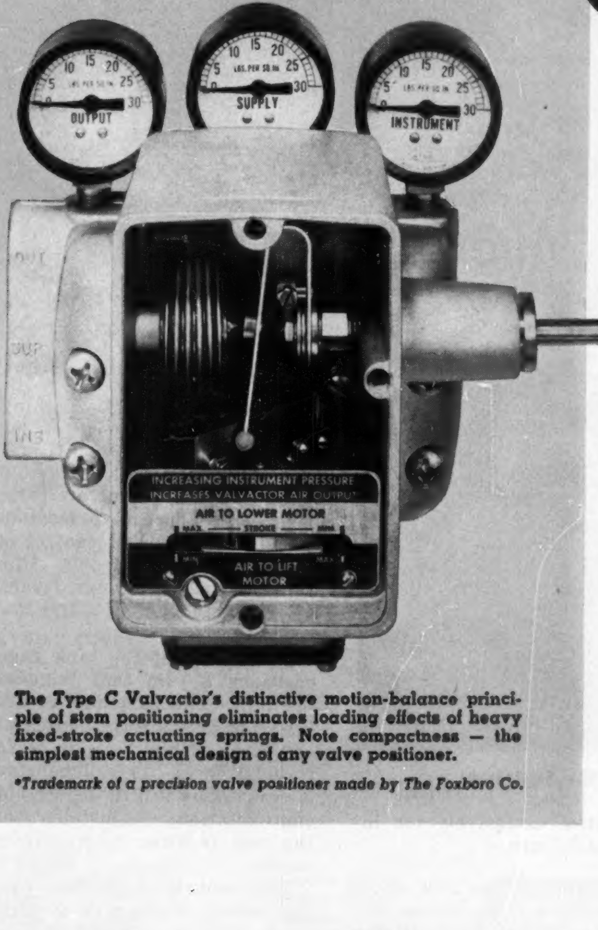
Specially treated, dipped and baked the motors resist moisture, dust and corrosive atmosphere. An extra-long flame path at the bracket fits and shaft hub chokes out flames before they can reach and explode the atmosphere. The motor is provided with a spark-proof aluminum fan as well.

The motors are available in gear, standard and variable speed models.—**Sterling Electric Motors, Inc., 5401 Telegraph Rd., Los Angeles 22, Calif. 300E**

NEW!

MOST UNIVERSALLY ADAPTABLE VALVE POSITIONER ON THE MARKET!

...the Foxboro Type C VERNIER VALVACTOR*



The Type C Valvactor's distinctive motion-balance principle of stem positioning eliminates loading effects of heavy fixed-stroke actuating springs. Note compactness — the simplest mechanical design of any valve positioner.

****Trademark of a precision valve positioner made by The Foxboro Co.***

Unique Flexibility Easily reversible in seconds. Sequencing by two simple adjustments.

Super Response Full air-pressure output to diaphragm motor on signal air-pressure change as small as ½ of 1% of signal span.

Extra Speed New, high capacity relay provides high speed positioning action.

Positive Positioning Direct, motion-balance feed-back assures instantaneous, pin-point positioning.

Now there's a positive-action, super-precision valve positioner that you can easily adapt to *any* diaphragm motor application — without exchange of parts! It's the Foxboro Type C Vernier Valvactor with unique motion-feedback.

The Type C Valvactor has a master setting disc which provides easy change of action as required by the control system, as well as easy reversal of Valvactor action for air-to-open or air-to-close control valves. Adjusting for limited stem travel is equally simple . . . sequencing of several valves is a cinch!

The Valvactor is the ideal solution to such problems as stem friction, plug friction, valve motor and transmission line lag, and extreme process line pressure changes. And it requires practically no maintenance! Available with 3-gauge and by-pass manifold, or plain manifold. Write for full details. **The Foxboro Company, 366 Neponset Ave., Foxboro, Mass., U.S.A.**

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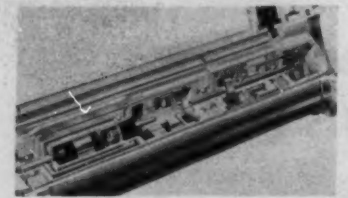
VALVE POSITIONERS



Inertial Mass Flowmeter

Gets the information by "weighing".

Density, temperature or viscosity of the liquid or gas flowing through this inertial mass flowmeter need not be known in order to get the mass rate reading.

A known, constant-angular velocity is imparted to the fluid by the meter. Deflection of a calibrated spring, proportional to the torque required to stop the rotation, is sensed by a signal generator. The true mass flow rate, proportional to the signal generator voltage, is displayed on a dial indicator or directed to a digital counter or totalizer.

Speed of the constant-speed drive of this unit is independent of temperatures, applied voltage and frequency which enhances the accuracy of the meter.—**Inertial Instrument, Inc., 2029 Broadway, Santa Monica, Calif.** 302A

Diaphragm Manometer

Links to recording and controlling instruments.

Intended primarily to actuate various controlling, recording and indicating instruments this diaphragm manometer measures vacuum, pressure and differential pressure. Only limitation; that the range does not exceed four inches of water and static pressure is not over 5 psig.

Fabricated for rugged and reliable service the large convoluted diaphragm is of Type 302 stainless steel fitted in an aluminum housing. A zero adjustment is accessible within the case and compensatory features are included for ambient temperatures of 50 F.—**Taylor Instrument Co., Rochester 1, N. Y.** 302B

Potentiometer-Recorder

Serves myriad of functions, is totally self-contained.

Touting maximum accuracy this new electronic null-balancing potentiometer-recorder measures, indicates, controls and records temperature, speed, strain, pH, and other quantities that can be resolved into electrical signals.

Completely self-contained except for the external sensing element, the recorder's most important application seems to be measurement and control of pyrometric-range temperatures. A simply operated instrument it is designed for minimum maintenance.

An outer door swings open 180 degrees to permit close examination of the chart. A wide selection of scale ranges is available and the instrument can be converted easily to any of them. The amplifier chassis uses plug-in readily available standard electronic tubes and components. — **Wheelco Instruments Div., Barber-Colman Co., Rockford, Ill.** 302C

Data Reduction

System exclusively for industrial use.

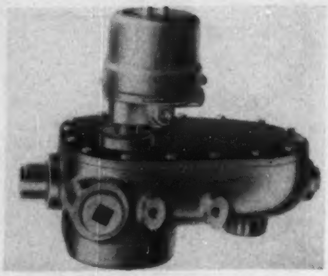
First unit of the new Beckman Data Handling System will be installed in Esso's Baton Rouge, La. pilot-plant refinery.

System will take electrical input signals from 50 sensing instruments and convert them to digital form for reproduction on paper tape, punched cards or automatic typewriter. System can be expanded to handle as many as 1,000 input signals.

This system can log all input signals within a minute. Generally, however, it logs them once an hour. In between readouts it continues to scan.

When an off-standard condition occurs, an alarm signal is given and the existing conditions are printed out.

A programming "pinboard" eliminates potentiometers and dial twiddling. Also, there's a grouping board which groups various inputs having the same program.—**Beckman Div., Beckman Instruments, Inc., Fullerton, Calif.** 302D



Pneumatic Level Control

For gas operated switching systems.

Designed for tank switching systems where gas or air pressure is the operating medium this pneumatic level control is available in two models. One trips the switch at high levels, the other at both high and low levels.

Float level of the tank gage positions a cam that triggers the unit. The cam can be adjusted to activate the switch at any level within a range of 24 ft. float level. This dimension is equivalent to 270 degrees of cam rotation. Adjustment of the cam is made by a vernier screw.

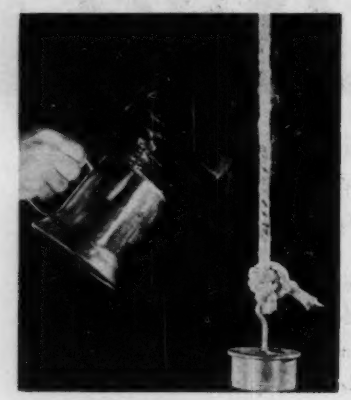
Both models of the level control mount on any type of automatic tank gages powered by a motor. And by means of an adapter kit these level controls can be used with tape-reading and high-pressure gages.—**The Vapor Recovery Systems Co., 2820 North Alameda St., Compton, Calif.** 302E

Borescope

Peers into large cavities to inspect without dismantling.

This optical instrument permits inspection of fabricated assemblies both during manufacture and while they are in service. Expensive dismantling costs are thus avoided when rivets, cracks, internal corrosion and other defects need to be examined. Ranging in size from ¼ in. to ¾ in. in diameter and from 20 in. to 72 ft. in length borescopes see into a wide variety of cavities such as cylinders, tubes, boilers etc.

High quality optical system permits examination without distortion. Detachable viewing heads afford a variety of observation angles such as forward, rear, lateral, oblique and wide angle. Accessory photographic attachments are available for taking photographs of areas under observation for closer and more leisurely study. — **Kollmorgen Optical Corp., 30 Church St., New York 7, N. Y.** 304A



Fiber Rope

Scorns extreme temperatures, is light and resilient.

Fiberfrax ceramic fiber has been spun into a lightweight, resilient rope that resists heat as high as 2,300 F. An aluminum silicate material, 30 ft. of ½ in. dia. weighs in at one pound —50% lighter than the other top heat-resistant rope material, asbestos.

The rope's high resiliency combined with its heat resistant property suits it for expansion joint packings, insulator wrapping and high temperature caulking, gaskets and seals.

Chemically inert the rope is unaffected by most furnace atmospheres including hydrogen. Woven in three-strand form, 15% of the braid consists of carrier-type fiber. Ultimately the rope will be produced in diameters ranging from ¼ in. to ¾ in. and in maximum lengths of 800 ft.—**The Carborundum Co., Niagara Falls, N. Y.** 304B

Microfilm Scanner

Handy and speedy, it fits into pocket.

A midget model microfilm scanner is designed for rapid reading of aperture cards either in jackets or unmounted. Sections of engineering drawings as well can be studied closely with it.

Cards are simply slipped into the slot under the optical lens and viewed against a white background in ordinary light. Affording four-times magnification, unit scans entire areas of films by shifting across the optical area.

Weighing only 5 oz. this hand-size scanner has a lens diameter of ½ in. and its over-all dimensions are 2⅝ in. wide, 1⅝ in. thick and 5 in. long.—**Filmsort Div., Dexter Folder Co., Pearl River, N. Y.** 304C

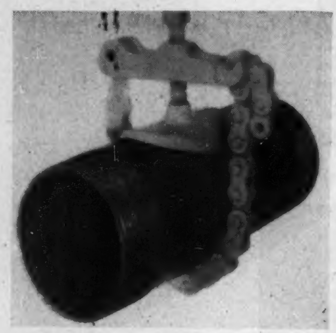
Insert Rings

Improve arc-welded surfaces.

Use of these insert rings offers various advantages to inert-gas tungsten-arc welding operations. On piping of over ¼-in. wall thickness the rings assist in obtaining uniform and smooth root-pass welds. On thin wall piping they improve the weld contour.

They often eliminate the need for a filler metal and require less weld passes for successful welding. Result is a cut in costs with a superior welded surface both in appearance and resistance to intergranular corrosion.

The consumable insert rings are available for all standard and special pipe and tube size diameters of 1¼ in. and larger. Mild steel, alloy steels and stainless steel are among the materials used for fabricating the inserts.—**Industrial Piping Div., Grinnell Co., Inc., Providence, R. I.** 304D



Pipe Tool

Pipe clamp and patch beats thumb in leak.

Accurately shaped steel patches with neoprene or asbestos gaskets are clamped into skin-tight seals directly over pipe breaks to repair leaks. Flow through pipe need not be cut-off to accomplish the repair.

Two styles of pipe clamps are marketed and materials other than the steel can be ordered for the patch. Saddle type clamps, in four sizes, are intended for 6-in. dia. pipes and under. Chain type clamps are available in all sizes for every pipe diameter greater than six inches.

Claimed to seal leaks up to 6,000 psi. patch can be welded for permanence at a convenient time. Without welding it represents an effective stop-gap measure for emergency leaks. One man can ordinarily effect the repair in 30 sec.—**Atlas Industries, Inc., P. O. Box 8152, Houston, Tex.** 304E

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about any item in this department, circle its code number on the Reader Service Postcard inside the back cover.

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KAMLOK'S POSITIVE SEAL ALL ALONG THE LINE ASSURES GREATER SAFETY IN HANDLING ALL TYPES OF LIQUIDS. Excellent hose has been condemned too often because of inferior couplings. To eliminate twisting, kinking, and straining, to add extra life and endurance to your hose use a good coupler . . . use KAMLOKS. Available in any combination to meet coupling requirements in sizes from ¾" to 4" inclusive. Sizes ¾" through 4" of special hard wear-resistant bronze and OPALUMIN*. 1" through 4" of monel, 1" and 2" (633A and 633B only) of stainless steel.
*OPW bi-tensile aluminum alloy.
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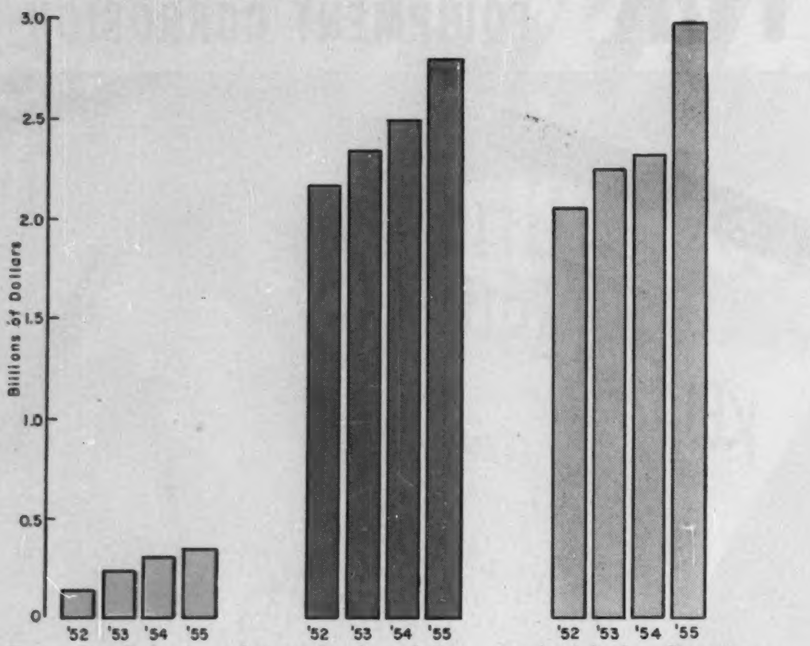
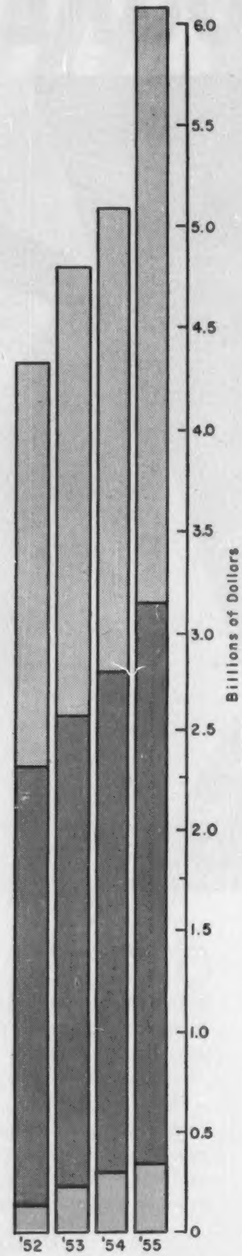
Chemical Economics

EDITED BY D. R. CANNON



Fast write-offs level . . . but regular depreciation . . . and retained profits soar so . . .



Total available cash

CPI Has Lots of Ready Cash

William H. Chartener, McGraw-Hill Dept. of Economics

Benefits from the fast tax write-offs adopted during the Korean War are tapering off for the chemical process industries, as they are for industry in general. This program has provided incentive for the construction of nearly $35 billion (all-industry) in defense and defense-related facilities—already in place or planned.

One might surmise—and many have—that with the tightening up on certificates of necessity last summer by the government, industry might be strapped for cash, feel less bullish about expansion.

Apparently such fears were groundless, for here is what is happening as fast amortization's influence wanes:

- Industry's aggressive building plans for this year and next (see next month's CE story on capital spending in the chemical process industries) are ample evidence that the gradual termination of five-year write-offs is not cramping expansion programs.
- Instead of "drying up" as rapid amortization fades, the supply of available capital is waxing strongly in an invitation to invest.
- In fact, the only important effect has been to make capital expenditure decisions more fully reflect management's judgment of specific profit opportunities. And there seem to be enough of these opportunities to make the added stimulus of emergency amortization unnecessary except in a few extreme cases.

▶ **What's in a Certificate?**—The attraction of the certificates of necessity carrying the fast tax write-off privileges is that investment in new plants and equipment can be completely amortized in five years rather than throughout the full useful life of the facilities. This means a larger deduction from taxable income for the company during the five years (though its tax liabilities can rise later on) and, hence, a faster return of cash to reduce debt, pay dividends or invest in more new plants and equipment.

This faster cash flow generated by accelerated amortization makes many companies more

willing to put their money into facilities where the long-term risks are great. Fast amortization also makes it easier for them to obtain outside financing.

Chemical industries are among those most favored in the award of certificates of necessity. According to the latest annual report of the Office of Defense Mobilization, the value of facilities authorized under certificates amounts to over $6 billion in the chemicals and allied products, petroleum and coal products, and pulp, paper and board mills categories.

▶ **Cash Return: Fast But Small**—While the value of chemical processing facilities being built under these certificates is imposing, the annual cash return through tax savings—or postponements, to be technically accurate—has been small.

From 1952 through 1955 the total tax deductions for emergency amortization in the process industries — chemicals, paper, petroleum refining, rubber and stone, clay and glass—came to just under $1 billion. What's more, deductions for emergency amortization have been growing by smaller amounts each year, should be at or near the peak now.

Meanwhile, regular depreciation and depletion allowances have been climbing fast and accounted for $9.75 billion in the same four years—nearly ten times as much as the total for fast tax write-offs.

▶ **Not All Fast, Either**—Ordinarily only part—about 60%, on the average, of the value of each approved project—of the total investment carried under certificates of necessity has been eligible for fast amortization. The rest must be treated as any other capital item in deducting depreciation for tax purposes.

▶ **Regular Write-Offs Speeded**—Actually, the new depreciation formulas authorized in the 1954 tax law offer fast depreciation privileges. Applicable to all new facilities, the new formulas can be almost as attractive as the certificates of necessity which are limited to defense-related projects.

The double-declining balance method permits depreciation of approximately two-thirds of total cost in the first half of a facility's useful life. The sum-of-the-years'-digits method runs close to three-fourths of cost in the first half of a facility's useful life.

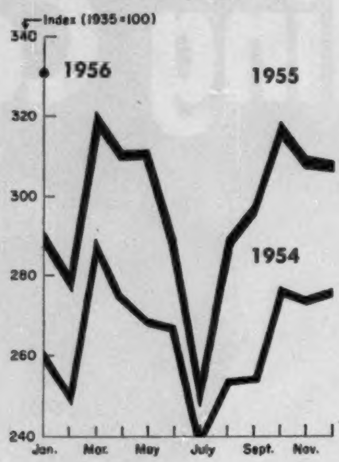
And remember that the five year amortization authorized by certificates of necessity permit 100% write-offs of only the approved portion in five years, a portion which usually covers 60% of total cost.

▶ **Healthy Profits Help** — Another factor eased the transition from five-year amortization for those companies which had come to rely on the certificates in deciding for or against doubtful projects — the improved profit picture. Profits have been especially good in the process industries since the lapse of the excess profits tax at the end of 1953.

After paying taxes and allowing for dividends, the process industries showed net retained earnings (net profits less dividends) of just over $2 billion in 1952. In 1955 the total rose to roughly $3 billion. Note that this is almost exactly equal to the $3.1 billion provided last year by regular depreciation, depletion and emergency amortization (see graph, previous page).

Since most of the money to finance new plants and equipment comes either from depreciation or from retained earnings, it's evident why chemical processors have a good supply of ready cash for expansion.

Chemical Consumption



Consumption by Industries

	Jan. (Final)	Feb. (Est.)
Coal products	12.5	11.8
Explosives	8.9	9.0
Fertilizer	84.7	80.4
Glass	24.7	24.8
Iron & Steel	19.9	18.6
Leather	4.3	4.4
Paint & Varnish	31.1	29.4
Petroleum refining	32.4	30.3
Plastics	25.3	26.2
Pulp & Paper	38.2	36.9
Rayon	32.4	30.2
Rubber	7.5	7.2
Textiles	11.6	11.2
Total	**333**	**320**

How About a Biennial Business Census?

Business could well use a biennial census of production and distribution. In an attempt to get such a service rolling, Associated Business Publications, Inc., is appealing to the President and Congress to set up every-other-year reports beginning with the calendar year 1957.

Arguing for the proposal, ABP's president, William K. Beard, Jr., pointed out, at a recent meeting, the need for matching industry's perfection of mass production techniques with a like perfection of mass marketing techniques. But to do this, he said, business must possess up-to-date knowledge of the patterns of national production and distribution as a guide to long-range planning.

Where must most of this data come from? ". . . only from the Census Bureau of the U. S. Department of Commerce because it alone has the legal authority to command the cooperation of all business firms in reporting necessary operating information," said Beard.

In climaxing his talk, Beard struck at the present inadequacy of census data with three jarring facts: The last complete published business census reflects conditions of eight years ago. The 1954 census, when published, will carry statistics at least a year and a half old. And with the national Census of Business scheduled now every five or six years, business can't expect better data until 1961 or 1962.

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with new, improved models of

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Here are typical examples of COWLES efficiency compared to ordinary equipment—

Fungicide preparation	Quick dispersion of reactants—finer particle size.
Paint premixes	Ultimate dispersion of pigments up to 10 times as fast.
Sodium dispersion	Smaller particle size. Cleaning problems eliminated.
Starch cooking (textile)	Equal quality at 1/8 the cost with 1/2 the power.
Ink premixes	Higher quality in half the time of paste mixer.
Gas dispersion	Smaller bubble size—better utilization of raw materials.
Plastisols and Organisols	Satisfactory products in a fraction of the time.

Let us prove it in your plant . . . AT OUR RISK!

You can expect the demonstration to prove that Cowles Dissolvers are the most compact, efficient machines on the market. They will handle a wide variety of materials with viscosities ranging up to and in excess of 50,000 centipoises. Direct peripheral action of new, patented impellers at 3600 to 6000 F.P.M. imparts high velocity to material, creates zones of intense turbulence and shear, breaks down agglomerates to ultimate dry particle size and surrounds each particle with a film of liquid. Operation may be by batch, semi-continuous or continuous.

Typical advantages include faster production, improved quality, greater yields, lower power consumption. All add up to better products at less cost—more profits for you.

If *milling* is required—for grinding or similar processing of organic, inorganic or synthetic materials, a new, improved Morehouse Mill will do the job up to four times as fast. Stainless steel construction prevents contamination—positive adjustment assures accurate end-product control and consistency.

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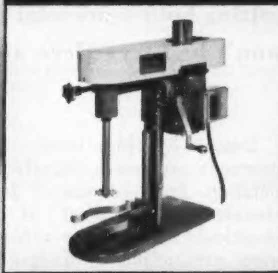
MANY MODELS TO CHOOSE FROM —special engineering adaptations if necessary

Wide variety of dissolver models and capacities. Tank types, mobile and tip-up units, special adaptations.



Laboratory dissolver model for testing, etc. Results identical to larger units.

Typical stainless steel unit, available in variety of models and sizes.

Laboratory mill for testing and small batches. Results identical to larger units.

Coke-Oven Chemicals*	Plenty Made		Plenty Sold
	1954	1955	1955
	(millions)		(millions)
Coke, tons	59.7	**75.2**	**76.3**
Coal tar, gal	715.8	**852.4**	**717.8**
Benzene, gal	138.3	**175.0**	**167.1**
Toluene, gal	33.4	**38.3**	**36.6**
Xylene, gal	10.0	**11.3**	**10.8**
Naphthalene, crude, lb	99.9	**184.6**	**173.3**
Ammonium sulfate, lb	1,645.6	**1,939.1**	**1,830.9**
Ammonia liquor, lb	32.2	**45.6**	**27.0**
Creosote oil, gal	26.5	**32.3**	**26.5**
Chemical oil, crude, gal	23.1	**26.9**	**26.9**
Solvent naphtha, gal	4.6	**5.5**	**5.3**

Source: U. S. Bureau of Mines
*Includes tar sold, used by producers or transferred to affiliates

More Coal Chemicals Wanted

Demand is—and will continue to be—strong. But getting both more coal tar and more chemicals out of tar won't be easy. Here are the possibilities and problems.

Despite competition from overseas producers, despite competition from domestic petrochemicals, the flood of coal chemicals spawned by straining steel production is finding lots of outlets. For even though coke-oven output of chemicals is growing steadily at a 3% clip each year, demand for these chemicals is running at least three times as fast.

Thus many coal chemical people are wondering how to best meet increased calls for these chemicals in the near future. Here are some courses they feel are open to them and the limitations of each:

- We can expect more coal tar from new coke-ovens. But with steel nearly blowing its top, capacity-wise, we won't see much more coal tar, for sometime, than we saw last year.
- We can get more coal tar from existing ovens and more chemicals from the tar. But the amounts we can get are limited and getting them may be very messy and costly.
- We can import more. But increasing dependence—already very substantial in some areas—on imports to ease shortages is a little risky what with revitalized foreign industries tending more and more to soak up surpluses of raw materials.
- We can expect industry to get more chemicals from petroleum and natural gas. This has been necessary to satisfy the country's chemical appetite. Indeed, markets for coal chemicals like phenol, toluene and xylene are already dominated by petrochemicals. But concession of new and growing markets to petrochemicals is not always justified. It may endanger markets or portions of markets now held by coal chemicals.
- We can turn to newer techniques for recovery of chemicals from coal (see table, p. 314). But these routes, though promising, are yet to be proved economical and, with the possible exception of low temperature carbonization, won't yield volume chemicals for some time.

▶ More Steel, More Tar?—Steel output is running at better than 90% of capacity. To squeeze out that last bit of production would mean putting beehive coke-ovens on stream—and no chemical byproducts are recovered from these.

Steel capacity will rise, of course, but probably only to 155 million tons by 1965. By present standards, this promises a little more than one billion gal. of coal tar—not much more, ten years from now, than the 850 million gal. turned out last year.

There's a factor tending to offset even this coal tar potential. Steel men use less and less coke each year per ton of pig iron produced. New techniques calling for more oxygen utilization in blast furnaces will require even less coke.

▶ Higher Yields of Tar?—In good years—when the demand and price for coal chemicals are right—less coal tar is burned as fuel by the steel industry. Even so, a minimum of 15% of available tar seems to be consumed in this manner each year.

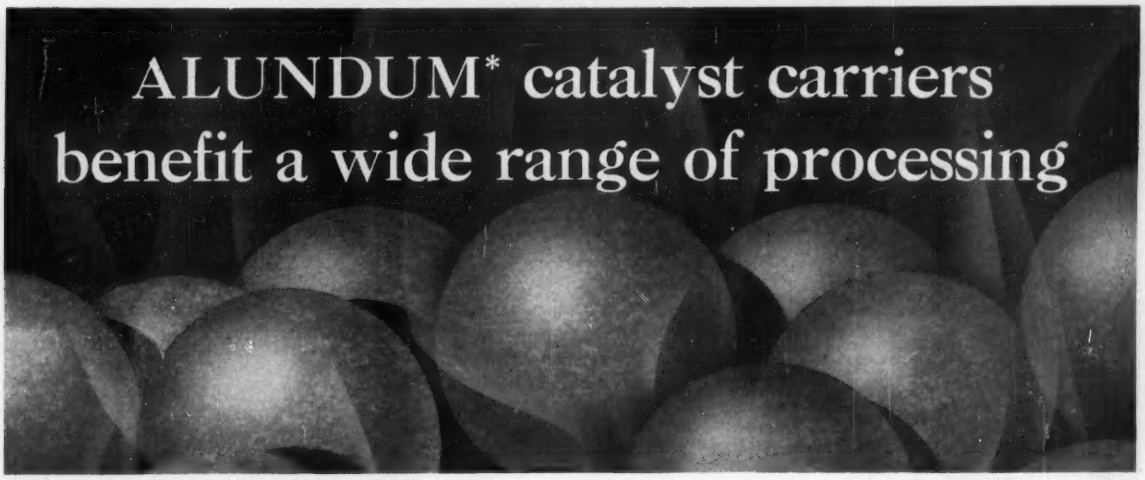
Naturally tar distillers would like more of this tar to work with. They say they can get more value from it than can the steel companies. Steel men, on the other hand, claim tar is a most efficient fuel under their hearths. What they lose by not selling coal tar they more than make up in production savings.

▶ Get More Out Of Tar?—Many coal chemicals are being recovered efficiently already. For example, yields of about 18 lb. of ammonia and 3.5 gal. of light oils per ton of coal are fairly standard. That's about as much as you can expect.

Other chemicals are in oversupply right now. Increase creosote yields and you add to an already overburdened market.

Naphthalene yields can stand a lot of improvement—and there's a lively demand for the stuff. But to get more naphthalene from coal tar you must accept a goodly amount of accompanying creosote—which you might not be able to sell profitably. If the excess creosote has to be burned at fuel oil prices then it would have been cheaper not to have recovered it (and the naphthalene) in the first place.

▶ Steel Industry Reluctant—Increasing coal chemical recovery within the steel industry is difficult. Even the Big Three (U. S. Steel, Bethlehem and Republic) have coking plants so small and widely scattered, for the most part, that to do an extensive job



Norton ALUNDUM (fused alumina) catalyst carriers are characterized by excellent mechanical, thermal and chemical stability. They have high resistance to abrasion and erosion, and their low density is useful for packing and filling applications. Catalytically, they are crystalline in nature and are produced in two surface area types: low and intermediate. Intermediate surface area carriers are subdivided into types A, B, C, with varying characteristics.

TYPICAL CHEMICAL ANALYSES (%'s)

	LOW SURFACE AREA	INTERMEDIATE SURFACE AREA
Al_2O_3	89.4–76.6	77.0
SiO_2	9.3–16.8	21.2
Fe_2O_3	0.5 – 1.3	0.2
MgO	0.1 – 0.6	0.4
CaO	0.1 – 0.8	
Na_2O	0.3 – 0.4	0.5
K_2O	0.1 – 1.0	0.2
TiO_2	0.2 – 2.5	0.5

PHYSICAL PROPERTIES

	Porosity	Water Absorption	Bulk Density	Vol. Bulk Density	Crystal Structure	Surface Area
Low Surface Area	40-50%	20-25%	1.90-2.10 gr/cc	65-80 lbs/ft³	Alpha Alumina	Less than 1m²/gram
Intermediate Surface Area Type A	50-55%	28-30%	1.65-1.70 gr/cc	58 lbs/ft³ (app)	Alpha, Gamma Alumina-chiefly Gamma	60-70m²/gram
Type B	50-55%	28-30%	1.65-1.70 gr/cc	60 lbs/ft³ (app)	Quartz, Alpha, Kappa, Delta Alumina-chiefly Quartz	20-30m²/gram
Type C	50-55%	28-30%	1.65-1.70 gr/cc	62 lbs/ft³ (app)	Alpha Alumina and Mullite	5-10m²/gram

Shapes and Sizes

Spheres: (Low surface area) 3/16″-1″ diam.; (Intermediate surface area) 1/4″-1/2″ diam. *Pellets:* (All carriers) 1/8″ x 1/8″ — 1/2″ x 1/2″. *Rings:* (All carriers) 1/8″ x 1/4″ x 3/8″ O.D. — 1″ x 1 1/2″ x 1 1/2″ O.D.

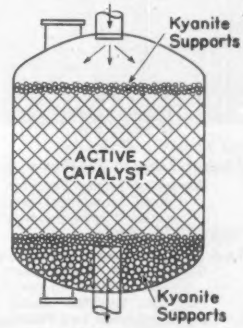
Typical Applications

Low Surface Area Carriers: phthalic anhydride, maleic anhydride, ethylene oxide, protective atmospheres, synthetic gas generation, grates or suspending beds for active catalysts.

Intermediate Surface Area Carriers: catalytic reforming, dehydrogenation, dehydration, sulfuric acid manufacture, nitric acid manufacture, dessicants.

In Suspending Beds For Active Catalysts

In addition to the carriers described here, Norton produces catalyst supports for use in fixed bed convertors where it is necessary to suspend active catalysts at a given level. Made of dense, rugged, chemically inert Kyanite material, these supports have great resistance to breakdown and have no chemically reactive effect on the processing.



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Get More Facts

on how ALUNDUM catalyst carriers and Kyanite supports can improve and economize your processing. Call in your Norton Refractories Engineer or write, mentioning your requirements, to NORTON COMPANY, 505 New Bond St., Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto 5, Ontario.

More Coal Chemicals Coming From These Projects

New Coke Ovens

Allied Chemical & Dye, Ironton, Ohio—New battery of 24 coke ovens in operation.
Inland Steel, Indiana Harbor, Ind.—87 new coke ovens to increase capacity by 445,000 tons coke/yr.—multimillion dollar project due in this summer.
Interlake Iron, Chicago, Ill.—50 new coke ovens planned.
National Tube Div., U. S. Steel, Lorain, Ohio—59 new coke ovens due late this year.
Republic Steel, Massilon, Ohio—31 new coke ovens planned.
U. S. Pipe & Foundry, Birmingham, Ala.—30 new chemical recovery ovens.
U. S. Steel, Gary, Ind.—installing new $50 million coke-oven unit, differing in conventional design, to give more naphthalene and other coal chemicals.
U. S. Steel, Provo, Utah—to boost light oil capacity and add facilities for recovery of phenol and byproduct ammonia.
Wisconsin Steel Works, South Chicago, Ill.—spending $5.2 million to modernize and increase coke capacity with 52 new ovens—to charge 3,000 tons/day of coal and get 2,000 ton coke, 35 ton ammonium sulfate, 1,000 ton naphthalene, 28,000 ton tar, 11,000 gal. light oils.

Improved Coal Tar Yields

Koppers Co. will build million-dollar pilot plant to search for more efficient recovery of aromatics—believes it can find uses for chemicals like carbazole and acenaphthene.
U. S. Steel had authorized units to remove thiophene and paraffins from benzene, toluene and xylene to meet clamor for purer aromatics—will use Scholven-Chemie light oil catalytic pressure refining process instead of usual acid-washing.

Improved Coke-Oven Gas Yields

Ketona Chemicals, Tarrant, Ala.—First U. S. synthetic ammonia plant based entirely on coke oven gas—after normal treatment for byproduct recovery, stripped oven gas to be used as hydrogen source—45,000 ton ammonia/yr.—complete this year.
U. S. Steel, Provo, Utah—a similar process to produce at rate of 76,000 ton/yr. ammonia in $20 million plant by middle this year.

Underground Coal Gasification

Alabama Power Co., Gorgas, Ala.—joint venture with Bureau of Mines, Stanolind and Sinclair Coal—now trying hydraulic fracturing of underground coal beds instead of electro-linking.

Lignite Carbonization

Alcoa, Rockdale, Tex.—producing up to 16,000 ton tar/day—Battelle seeking ways to extract chemicals from the tar—findings available to sponsors Alcoa, Texas Power & Light, Barrett, Carbide, Celanese, Koppers, Spencer, etc.
Dakota Briquet & Tar Products—distills lignite tar to creosote oil and pitch.

Coal Hydrogenation

Bureau of Mines, Bruceton, Pa.—bench-scale experiments using better catalyst and higher temperatures point to one-step process for liquid fuels and chemicals.
Pittsburgh Consolidation—building $3 million plant for hydrogenating carbonization products to get cresols, phenol, cresylic acids, resins—due middle this year.

Steam Carbonization

Dow Chemical, Midland, Mich.—seeking aromatic acids by pulverizing bituminous coal, suspending in NaOH solution and oxidizing at 270 C. and 900 psi.—research aimed at fractionation of product mix.
Du Pont, Belle, W. Va.—burns coal in fluidized bed in atmosphere of steam and deficient oxygen to produce CO and hydrogen—process tried on large scale to make ammonia synthesis gas, eliminate coke-ovens and gas producers.

Philadelphia Electric, Schuylkill Station—crushed coal is charged to a fluidized bed in a preoxidizer where it's devolatilized and dried—then carbonized with steam—yields are 22-27 gal. tar, 3-4 gal. light oil, 1,450 lb. char per ton of coal.
AEC and Bureau of Mines—pulverized coal, steam and oxygen piped through nuclear reactor to make syntheis gas—a new reactor now gives higher gasification rates, a better gas.

Fischer-Tropsch Synthesis

Bureau of Mines, Bruceton, Pa.—using rugged catalysts which may make possible a more economical process than that abandoned years ago because the catalyst couldn't take the treatment.

Low Temperature Coal Carbonization

Cotarco, Inc., Colo.—plans $12 million plant to process 8,250 ton/day of coal in new process—to get char, fuel gas, acid oil, light oils, creosote, pitch, sulfur.
PDP Co., Lewiston, Idaho—plans plant for char and chemical byproducts.
Olin Mathieson and Pittsburgh Consolidation, Ohio Valley—Pitt-Con. will process 5,000 tons/day of coal to produce char and byproduct chemicals—the char will be burned to produce power for aluminum plant.

on creating new recovery units is very costly.

Add to this the prime and overriding responsibility of coke-oven operators—to produce the best coke—and you can better understand why they are not more interested in chemicals.

▶ Ammonia from Coke Gas—There's one chemical, though—anhydrous ammonia—that a lot of people are interested in getting from coal or, to be more accurate, from coke-oven gas. U. S. Steel and Ketona Chemicals (a joint venture of Hercules Powder and Alabama Power) are putting in capacity to produce a total of 115,000 tons/yr. of ammonia from this source.

There's a double benefit in this. Not only can you make ammonia fairly cheaply but the coke-oven gas, after being stripped of hydrogen, is a better fuel than before.

▶ Mild Carbonization—Perhaps the method closest to turning out important amounts of varied coal chemicals is the low temperature carbonization of lignite or coal (coke-making is a high temperature process).

Alcoa, Texas Power & Light and a host of chemical companies are in on a project whereby Alcoa's Rockdale, Tex., aluminum plant will use electricity generated by lignite combustion. Texas Power hopes it can justify burning the lignite to a char (Alcoa could use lignite that's merely been dried) by recovering, and finding a market for, chemicals in the lignite tar.

There are problems, though. Tar yields are low, less than 15% of lignite input. No naphthalene fraction has been obtained and the high tar acid content has a lot of high-boiling fractions unlike commercial fractions. And the cost of lignite carbonization must be carried chiefly by the chemical values realized.

Another aluminum producer, Olin-Mathieson, is in a similar venture with Pittsburgh Consolidation. Pitt Consol will carbonize coal to give Olin's Ohio Valley plant a more efficient fuel in char form, and give themselves some interesting chemicals.

It's significant that aluminum producers, long used to cheap water power, are resorting to carbonized coal. Area logistics are the big attraction, to be sure. But Alcoa and Olin-Mathieson no doubt feel there's a good chance for profitable chemical recovery (and cheaper fuel thereby) in the offing.

▶ Coal Hydrogenation—To put it bluntly, hydrogenation is expensive. Yet it may become the most fruitful route to chemicals from coal.

Fuel production via hydro-

genation—with its very high temperatures and pressures—is not conducive to maximum chemical recovery. Milder methods appear to break coal down in more usable segments.

Product balance poses marketing difficulties. Although 3-8 times as much naphthalene comes from hydrogenation as from coke-making, 70 times as much phenol may also come along with it.

Yet yields of relatively rare chemicals are so markedly increased (e.g. 400 times as much quinoline) that many products may for the first time find widespread use. And chemicals like aniline, not ordinarily recovered in coke-oven operations, may now be obtained from coal.

But perhaps coal hydrogenation's most provocative potential of all is this: Application to oils, tars, gases stemming from any other method, whether it be low temperature carbonization or gasification or conventional coking.

GUIDED TOUR CONTINUED

NH_3 from coke-oven gas

For handing ammonia manufacture a new hydrogen source low-temperature technology may gain full citizenship in the chemical process community. Starting material at Ketona's new ammonia plant: coke-oven gas. (p. 400)

Your letters let us know!

Welcomed by the Editor, our readers' views sweep wide range of topics, add another dimension to our coverage. (p. 424)

New technical literature!

You can now get—free and fast—literature on any subject in your field. Keep your files up to date the easy way.

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Inside Back Cover

Using

DU PONT ELASTOMERS

NEOPRENE - HYPALON®

in Industry

HYPALON® hose carrying 98% sulfuric acid outlasts ordinary hose 16 to 1

Four months' service from a hose that loaded three tank cars a week with 98% sulfuric acid! That's the report from one southern phosphate company after switching to acid hose with tube of HYPALON, Du Pont's new synthetic rubber.

Before the change, regular acid hose had to be replaced after only one week . . . meaning just three tank-car loadings a hose. Yet the HYPALON tube hose was still in good condition after sixteen weeks. The difference lies in the superior resistance of HYPALON to acids—especially strong oxidizing acids.

Striking comparisons like this show what happens when HYPALON products are used for those *extra-tough* service applications. Replacement costs are cut . . . maintenance is drastically reduced. HYPALON products deliver top performance under the most severe conditions. High ozone concentrations, strongly oxidizing chemicals, high temperatures—rugged HYPALON can take them all and still give long-term service.

When you need a rubber product that must have *extra-high resistance* to deterioration, it will pay you to investigate HYPALON. Clip the coupon for further information.

ACID HOSE OF "HYPALON" in action, loading 98% sulfuric acid.

NEOPRENE coatings last 12 times as long as acid-resistant paints on tank trucks

FOR THE TANK SPLASH AREA (shown above), a black neoprene coating (brush) is used. For the rest of the tank, a grey coating is applied (spray).

Resist caustic soda and aluminum chloride; nitric, muriatic and other corrosive acids

Chemical Tank Lines, Inc. of Downington, Pa., reports that neoprene coatings applied externally have lasted 12 times as long as the best acid-resistant paints on the dome and center-sheet area of its acid tank trucks.

The company first tried a neoprene coating on only one of its tank trucks. The neoprene coating lasted over two *years* with only minor touching up and was still serviceable. The best acid-resistant paint previously used lasted only two *months*. This cost-saving performance persuaded Chemical Tank Lines to apply neoprene coatings to all of its 64 trucks.

First cost of the neoprene coatings is higher, says Earl D. Radcliffe, superintendent of operations, but "it looks like we'll only have to do the job every other year instead of six times a year. The net result should be that we keep our trucks painted for 1/6 the materials cost and 1/12 the labor cost." Mr. Radcliffe also reports that in addition to material and labor costs he loses $100 in revenue every time a truck is brought in for repainting. This amounts to $600 a year per truck with acid-resistant paint, only $50 a year per truck with neoprene coatings. And the company expects 4 years extra service from trucks coated with neoprene, thus reducing the cost of tank depreciation by $800 per year per tank.

Neoprene coatings are only one of many neoprene products that may help you reduce your company's cost of operation. Neoprene is also used in hose, belting, gaskets and scores of other products where resistance to chemicals, oil, grease and outdoor exposure is necessary, service conditions which quickly deteriorate ordinary rubber. Ask your rubber-goods supplier about neoprene, or mail the coupon below. We'll be glad to send further information.

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Elastomers Division, Dept. CE-6
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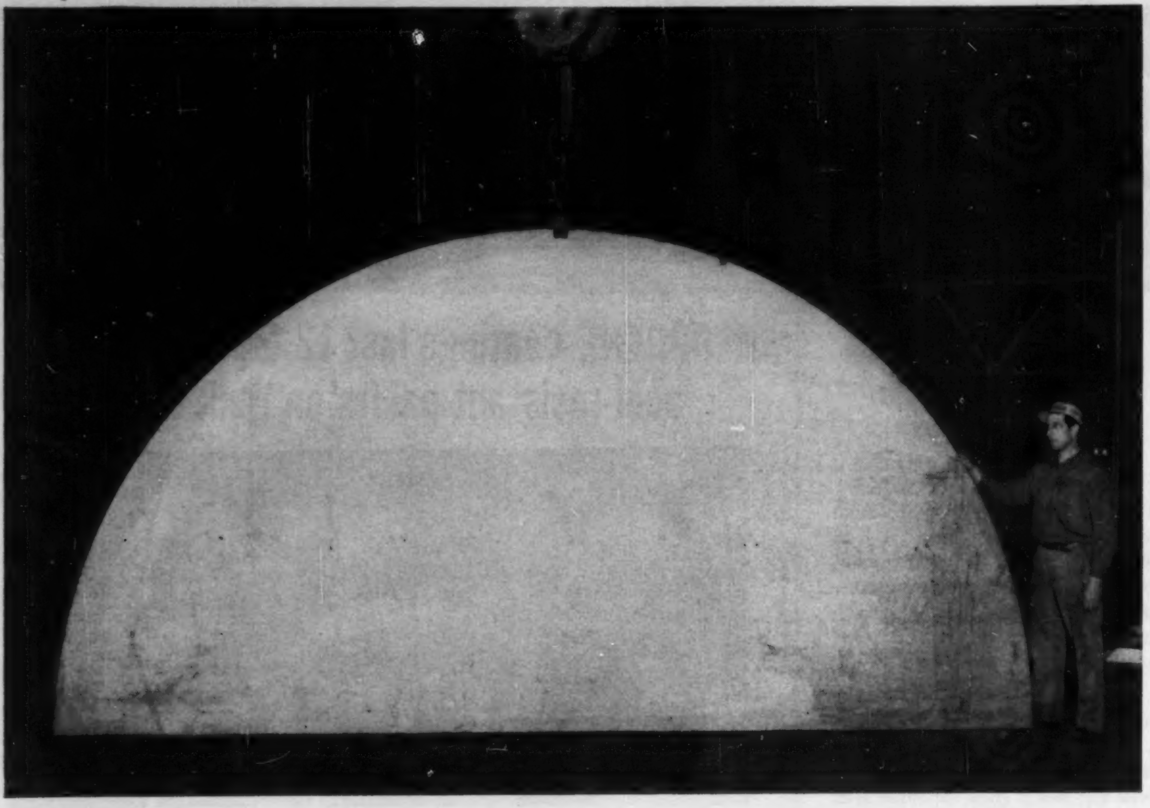

Carlson specialized service keeps your costs low

Here's how Carlson *specialized service* in stainless plate worked on this job.

The illustration shows one of two segments of a tank head blank. Made of 1" thick, Type 302 stainless steel, the head blank measures 210" in diameter and weighs approximately 9000 pounds. Each segment was produced so accurately the customer did not have to "true up" the abrasive cut straight edges before welding the two segments together. This meant the customer had what he wanted, the way he wanted it—produced to his exact requirements.

And here's why you'll want this *specialized* Carlson service.

More than once we've helped a customer do his job easier, quicker and at lower cost by efficient planning and expert use of specialized equipment. This experience can work to your advantage, too. You can buy *exactly* what your specifications call for—and nothing more. This saves freight charges on material you cannot use. It also saves the cost and trouble of handling scrap in your shop. And you can set up a faster production schedule based on receiving what you want, when you want it.

Stainless steel is our *only* business—and we know it! Let us show you how this *specialized service* can help you. Your inquiry will receive prompt attention.

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G. O. CARLSON, INC.

THORNDALE, PENNSYLVANIA

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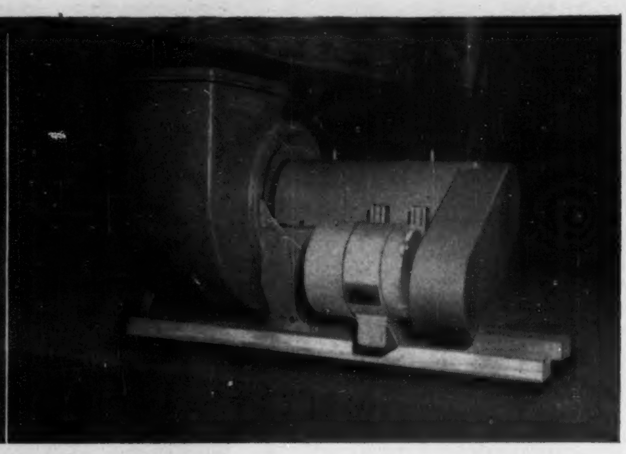
District Sales Offices in Principal Cities



Inlet side showing cast iron inlet cone with integrally cast guide vanes. Fan is an Arrangement 9 package unit with monel wheel.

Drive side showing enclosed motor, belt guard and rain shield over ball bearings and shaft drive.

"BUFFALO" HIGH-EFFICIENCY CAST IRON FANS ARE SAVING MONEY ON CORROSIVE FUME INSTALLATIONS

Developed by "Buffalo" engineers to meet a specific request for high efficiency fans to operate under extremely corrosive condition, these fans combine cast iron durability with the well-known high performance of "Buffalo" Limit-Load® Fans. These No. 2½ Type "LL" Fans are popular with the chemical and process industries; one large manufacturer having over 1,000 units installed on chemical fume hood exhaust.

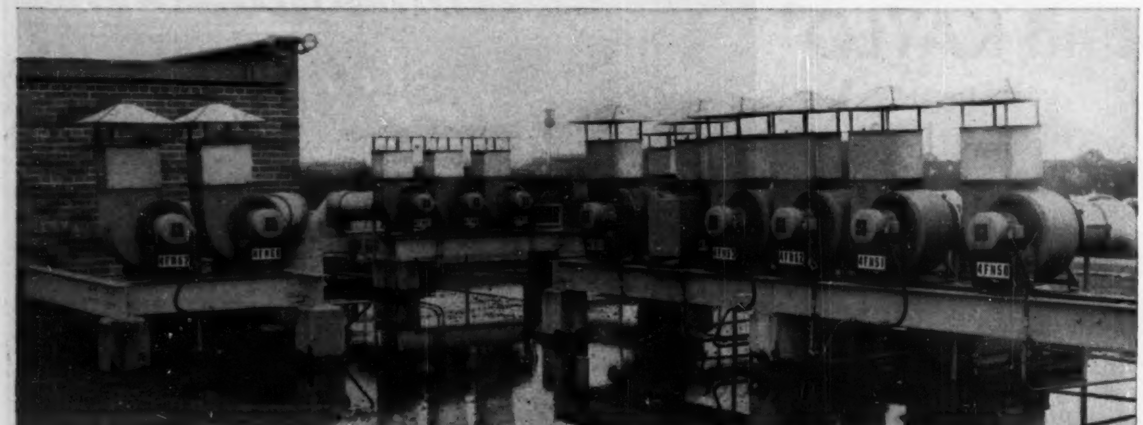
Rugged cast iron housings and cast inlet cones with integrally cast inlet vanes, guide air smoothly into the wheels, for the low-turbulence air flow inherent in this high efficiency design.

As with all "Buffalo" Fans, these have the famous "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.

These fans have the backward curved blade wheel, non-overloading, regardless of system pressure. Standard wheels are monel but can be supplied in stainless or protective coated steel or of Everdur or aluminum for explosive atmospheres.

Three arrangements are available: with direct motor drive, separate belt drive or as a package unit with adjustable pitch V-belt drive and motor mounted on adjustable base rails.

Your inquiries on these rugged chemical-industry fans are invited. Write today on your company letterhead.



Roof exhaust installation at a major chemical and dye plant.

"Buffalo"

BUFFALO FORGE COMPANY

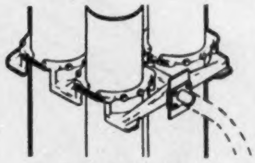
BUFFALO, NEW YORK

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

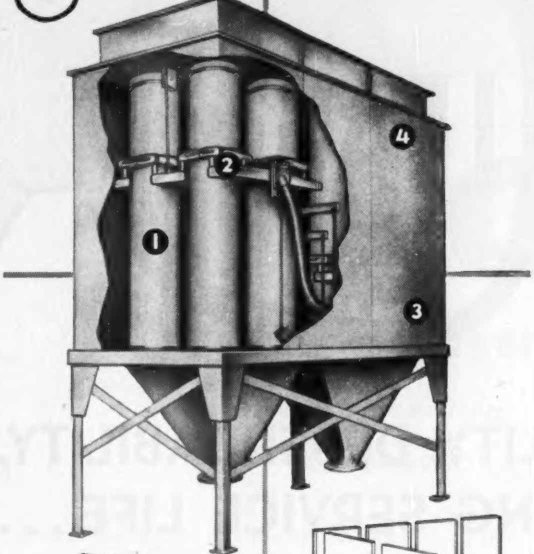
VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

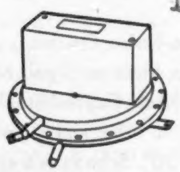
AND HOLDING ON BY A MAGNET! There's quite a drop at the feet of this scaffold worker . . . but he is in no danger. He is holding on by a permanent-

1 Uniformly dense felt filter bags... of wool or synthetics...produce maximum filtering efficiency yet have 6 times flow rate of ordinary woven filter material. Tiny pores catch and hold even sub-micron-sized particles. Bags measure 12″ in diameter... up to 18′ in length.

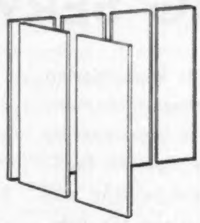


2 Exclusive reverse-air-jet action cleans entire bag area uniformly and automatically. Blow rings* travel up and down length of bag exterior . . . blowing through bag to remove accumulated dust from bag walls. Automatic cleaning never interrupts peak filtering efficiency.





3 Automatic pressure switch* eliminates overcleaning . . . prolongs bag life. Switch controls blow ring operation. Above normal pressure loss actuates rings which stop when pressure loss normalizes. Automatic self-cleaning occurs as often or as seldom as needed.



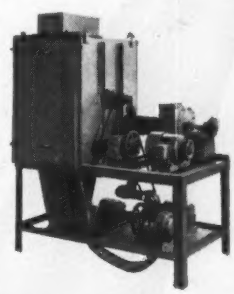
4 Prefabricated Aeroturn can be installed in one-quarter the time required by ordinary dust collectors of similar capacity . . . in half the space. Aeroturn arrives from the factory in easy-to-assemble prefabricated sections.

50% LOWER MAINTENANCE COSTS and 99.9%+ EFFICIENCY

with KOPPERS Series 12 Aeroturn Dust Collectors

Up To 75% Lower Installation Costs . . . Up to 50% Less Space! You can get rid of dollar-consuming dust far more economically with a Koppers Series 12 Aeroturn than with a conventional collector. The Aeroturn Dust Collector costs you less to install and maintain . . . occupies far less space. A Koppers Series 12 Aeroturn operates continuously and automatically at highest filtering efficiency.

Aeroturn's remarkably high filtering efficiency sends your plant and machinery maintenance costs way down. Your heating and cooling costs fall because you can recirculate air . . . cleaner than outside air. Koppers Series 12 Aeroturn Dust Collector is available with from 4 to 64 filter bags . . . Aeroturn's capacities range from 1,000 to 60,000 CFM. It only takes a few minutes of your time to discover for yourself the many cost-saving features of the Koppers Series 12 Aeroturn.



Factory-assembled and test-operated, Koppers Model D Aeroturn Dust Collector combines features of Series 12 with unusual compactness. Capacities range from 500 to 4,800 CFM.

AEROTURN DUST COLLECTORS

KOPPERS ®

Koppers Company, Inc.
Metal Products Division
Industrial Gas Cleaning Dept.

Engineered Products Sold with Service

*Hersey Patents

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Koppers Company, Inc., Industrial Gas Cleaning Dept., 5006 Scott Street, Baltimore 3, Maryland.

Gentlemen: Please send me a free copy of your Aeroturn Booklet with descriptions, drawings and photographs. ☐ Series 12 ☐ Model D

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. . . And WELDCO Tubular Products keep moving ahead as more and more buyers discover their many important advantages. WELDCO is produced by specialists — men who have the equipment, facilities and experience to manufacture pipe and tubing to your exact specifications. It's automatically machine-welded under pressure, properly formed, carefully finished, accurately sized and straightened, and rigidly checked. And remember, too, only WELDCO is welded with the exclusive Double-Fusion Process. . . . It's available in Stainless Steel, Monel, Inconel, Nickel, Cupro-Nickel, and Hastelloy, in tube and pipe sizes from 3" to 30", Schedules 5 and 10, and 3" to 12", Schedule 40. To get lightweight, corrosion-resistant Tubing with complete uniformity and long service life, always specify WELDCO — your best buy in top-quality tubing.

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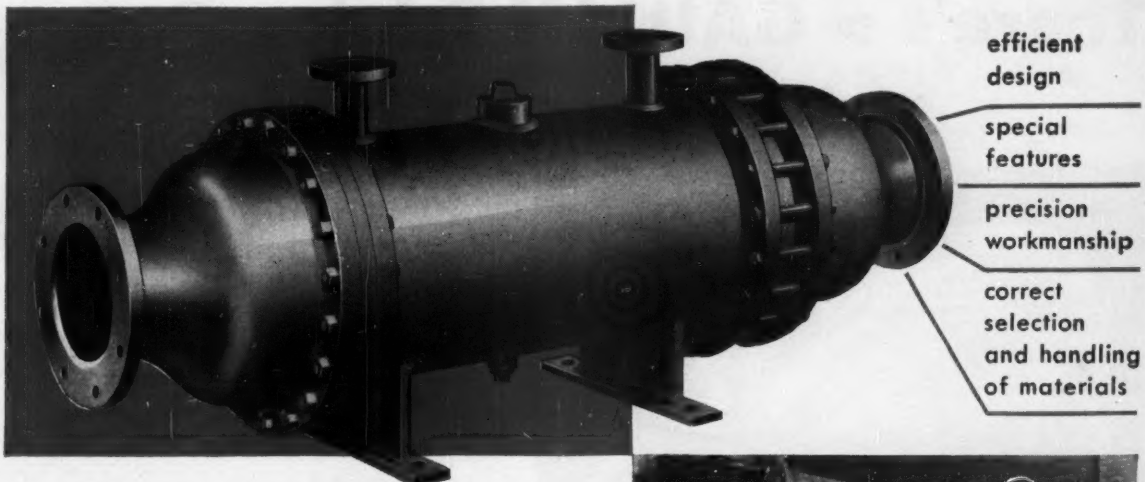
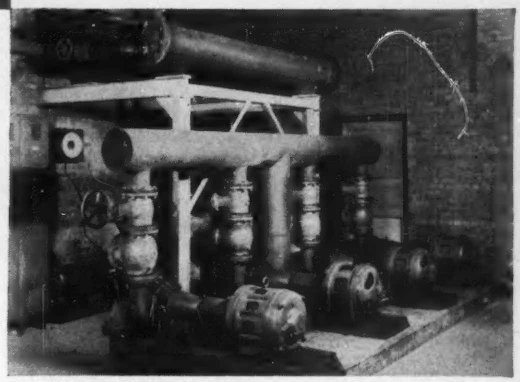


Why B&G Heat Exchangers give the service you expect



Installation of B&G Heat Exchangers and Centrifugal Pumps.

Whether you need an off-the-shelf or a custom-built unit, B&G offers quality and performance perfected in a quarter century of manufacturing heat exchange equipment.

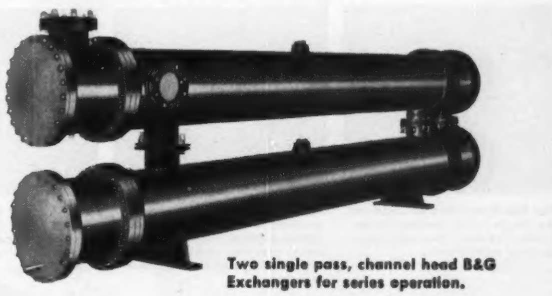
Starting with proper selection and handling of materials, B&G Exchangers are built to designs of proved efficiency and with uncompromising workmanship. Ample material thicknesses in every detail and high tensile strength bolting are assurance of strength and long operating life. Full tube bundles and close tolerances between shell wall and baffles prevent slippage of fluid and assure maximum heat transfer. Units can be furnished with tubing of copper, steel, several of the stainless steels and other non-ferrous alloys.

B&G Heat Exchangers are built to ASME Code U-69 requirements and can be certified by Hartford Steam Boiler and Inspection Service.

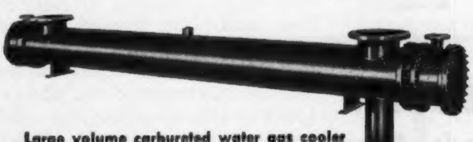
The B&G engineering staff is always available for consultation on your heat exchange problems. Send for catalog showing application range of B&G Heat Exchangers.

STANDARD DESIGNS OR ENGINEERED TO YOUR REQUIREMENTS

High pressure B&G Exchanger with fixed tube sheets and expansion joint design.



Two single pass, channel head B&G Exchangers for series operation.



Large volume carbureted water gas cooler using sea water for cooling, with cupro-nickel tube-side construction.

BELL & GOSSETT COMPANY

Dept. EJ-14, Morton Grove, Illinois

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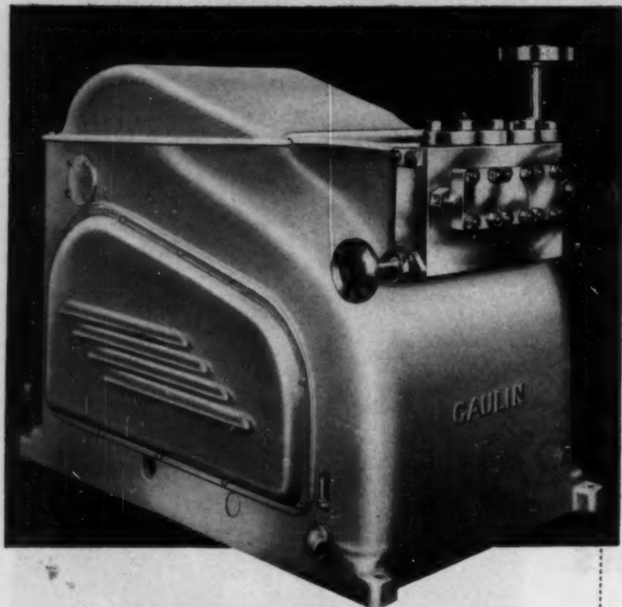
There's a GAULIN Triplex Pump for every job



With Maintenance-Saving Horizontal Design Stainless Steel Construction

For Transfer, Metering, Spray Drying

A Gaulin Triplex Pump is a rugged, heavy-duty machine built to minimize operating, inspection, and maintenance costs. Compact. Simple. Dependable. Its horizontal design positively separates your product from the crankcase . . . and makes every part easy to get at.

Just lift two plates and a Gaulin drive and plunger assembly is convenient for inspection or repair.

A Gaulin Cylinder may be disassembled in a matter of minutes.

Vibrationless. A Gaulin is practically free of vibration.

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Rugged Dependability. Thousands of installations with well-known companies prove a Gaulin provides unusually long service at minimum cost.

Write for Bulletin

Name Your Capacity

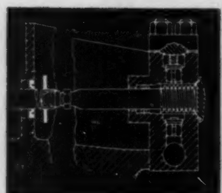
There's a Gaulin to handle your capacity from 50 GPH up to 5000 GPH.

Name Your Pressure

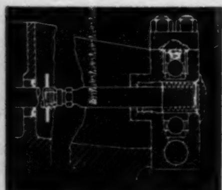
Gaulins are designed for 3 basic pressure ranges — up to 3000, 5000 and 8000 psi.

Name Your Product

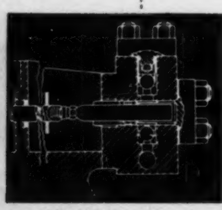
Only Gaulin designs a specific cylinder to handle every product efficiently, economically. Note some of our designs below.



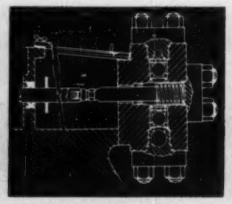
For Fluid, non-abrasive products the Gaulin Spring-Loaded Poppet Valve provides low initial cost and low maintenance.



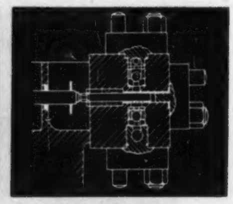
For Viscous, heavy-bodied products, the Gaulin Ball Valve (spring-loaded packing, inserted seats) provides excellent pumping efficiency and minimum maintenance.



For Slightly Abrasive, viscous products, the Gaulin Ball Valve (adjusting screw packing, inserted seats) keeps maintenance costs down.



For Slightly Abrasive, viscous products, where maintenance must be accomplished in minutes, the Gaulin Ball Valve with removable seats (spring-loaded packing) cuts maintenance time to the bone.



For Very Abrasive products, the Gaulin Ball Valve (with adjusting screw packing, removable seats) provides the ultimate in low cost maintenance.

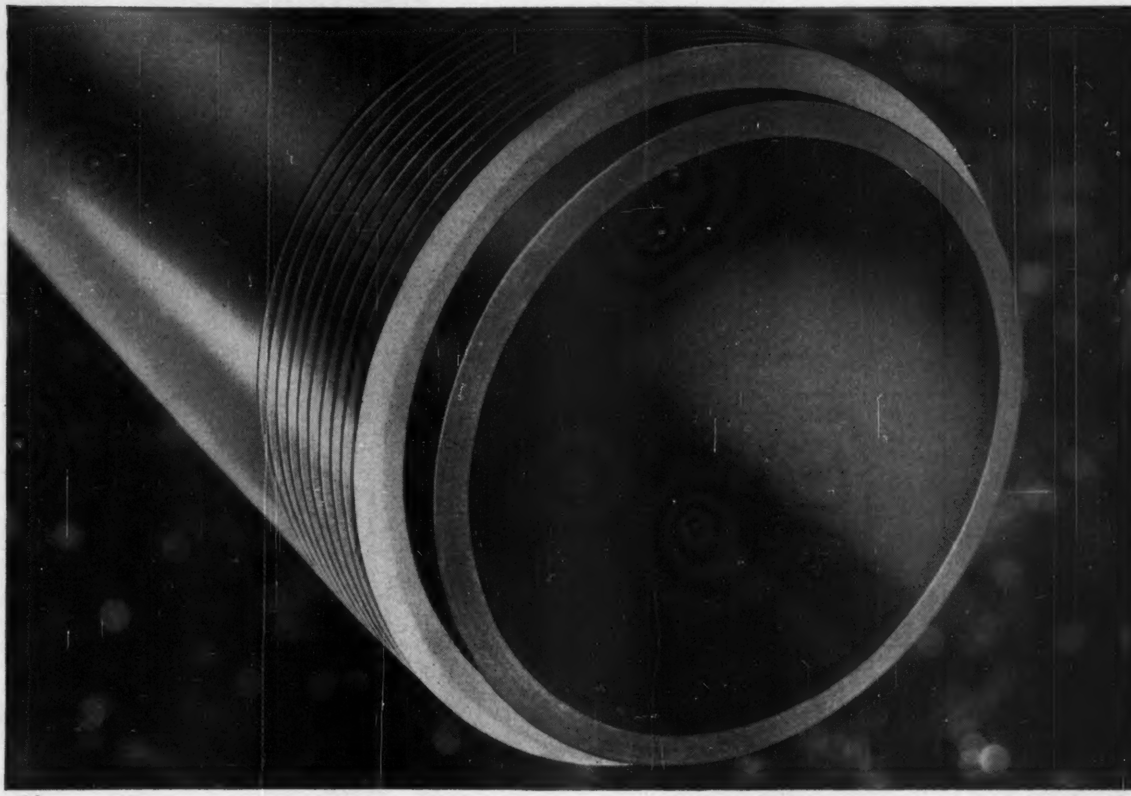
Gaulin TRADE MARK

Manton-Gaulin

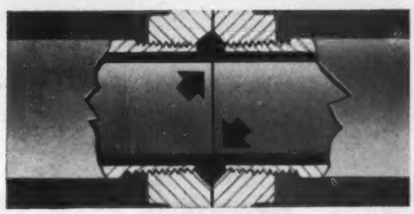
Manufacturing Company, Inc., 71 Garden St., Everett 49, Mass.

WORLD'S OLDEST AND LARGEST MANUFACTURER OF HOMOGENIZERS, COLLOID MILLS, TRIPLEX STAINLESS-STEEL HIGH PRESSURE PUMPS

DOW



You can see why Saran Lined Pipe prevents corrosion



Liquid never touches metal in Saran Lined Pipe even at a flanged connection like this.

Acids, alkalis and other corrosive liquids never touch the rigid steel pipe . . . it's continuously lined with durable, corrosion-resistant saran

Say good-by to corrosion problems when you install saran lined pipe, fittings, and valves. This combination of corrosion-resistant saran swaged into rigid, non-bursting steel has a proved record of corrosion prevention in the chemical, petroleum, waste, pulp and paper, metal finishing and food processing field.

Saran lined pipe, fittings and valves form tight, snug, leakproof joints . . . is available for working pressures up to 150 psi. Fittings and valves are also available in steel for working pressures to 300 psi. You'll be amazed how easy and economical it is to install this modern piping, too. For it can be cut and threaded in the field with available pipe fitters' tools. And because it's rigid, a minimum of supporting structures are needed.

For further information on saran lined pipe, fittings, and valves send in the coupon on the right today. THE DOW CHEMICAL COMPANY, Midland, Michigan.

Saran Lined Pipe Company
2415 Burdette Avenue
Ferndale, Michigan
Dept. SP627A

Please send me information on saran lined pipe, valves, and fittings.

Name________ Title________

Company________

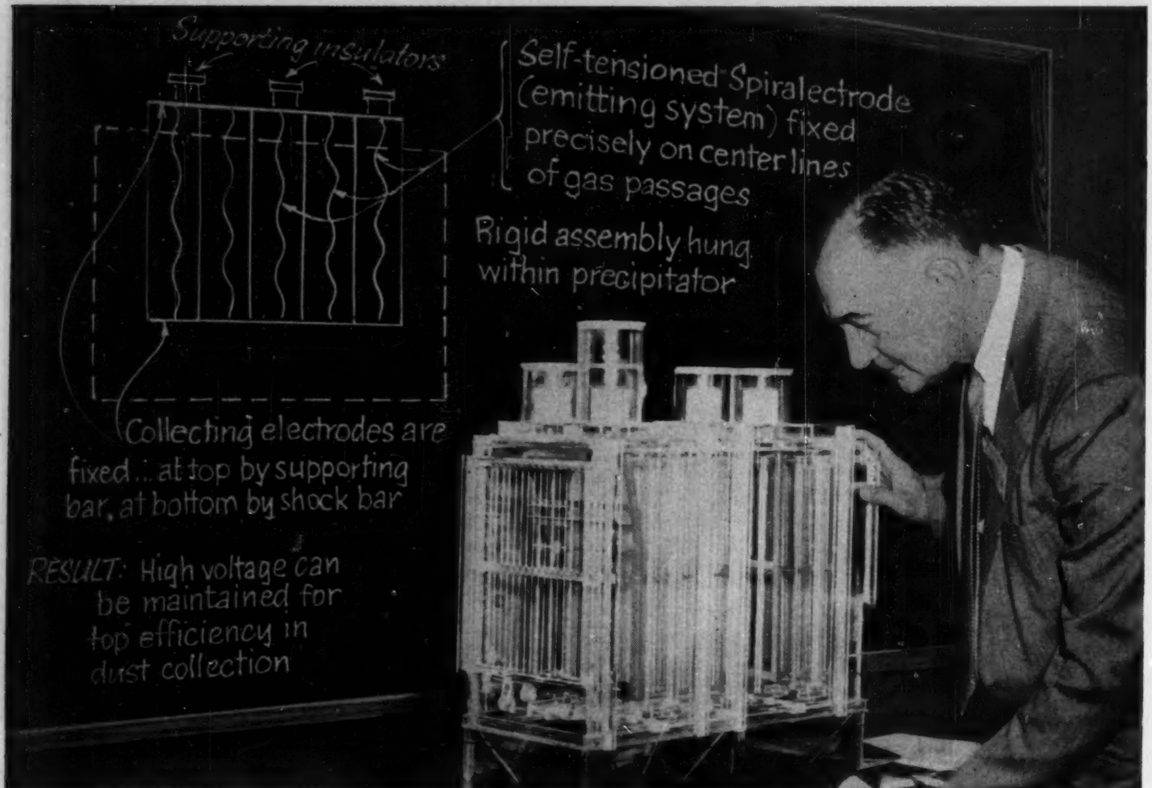
Address________

City________ State________

Saran Lined Pipe is Manufactured by The Dow Chemical Company, Midland, Michigan

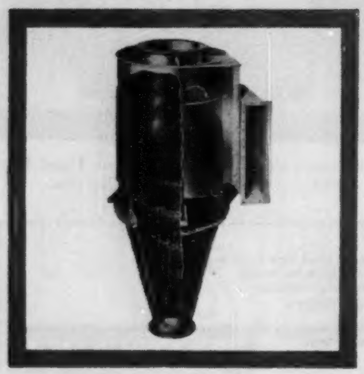
you can depend on DOW PLASTICS DOW

How fixed electrodes assure top efficiency in a Buell "SF" Precipitator

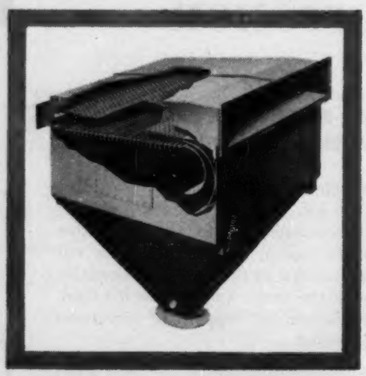


PHOTOGRAPH OF BUELL PLASTIC MODEL BY INDUSTRY & POWER

Even when high-resistivity dusts must be collected, top efficiency is guaranteed by the exclusive shape of Buell's Spiralectrodes—proved to give 50-100% greater emission than straight wires. Exclusive Continuous Cycle Rapping virtually eliminates maintenance by keeping electrodes constantly clean.



Buell Cyclones also assure top efficiency with large diameter design to eliminate clogging . . . and by harnessing double-eddy and putting it to work.



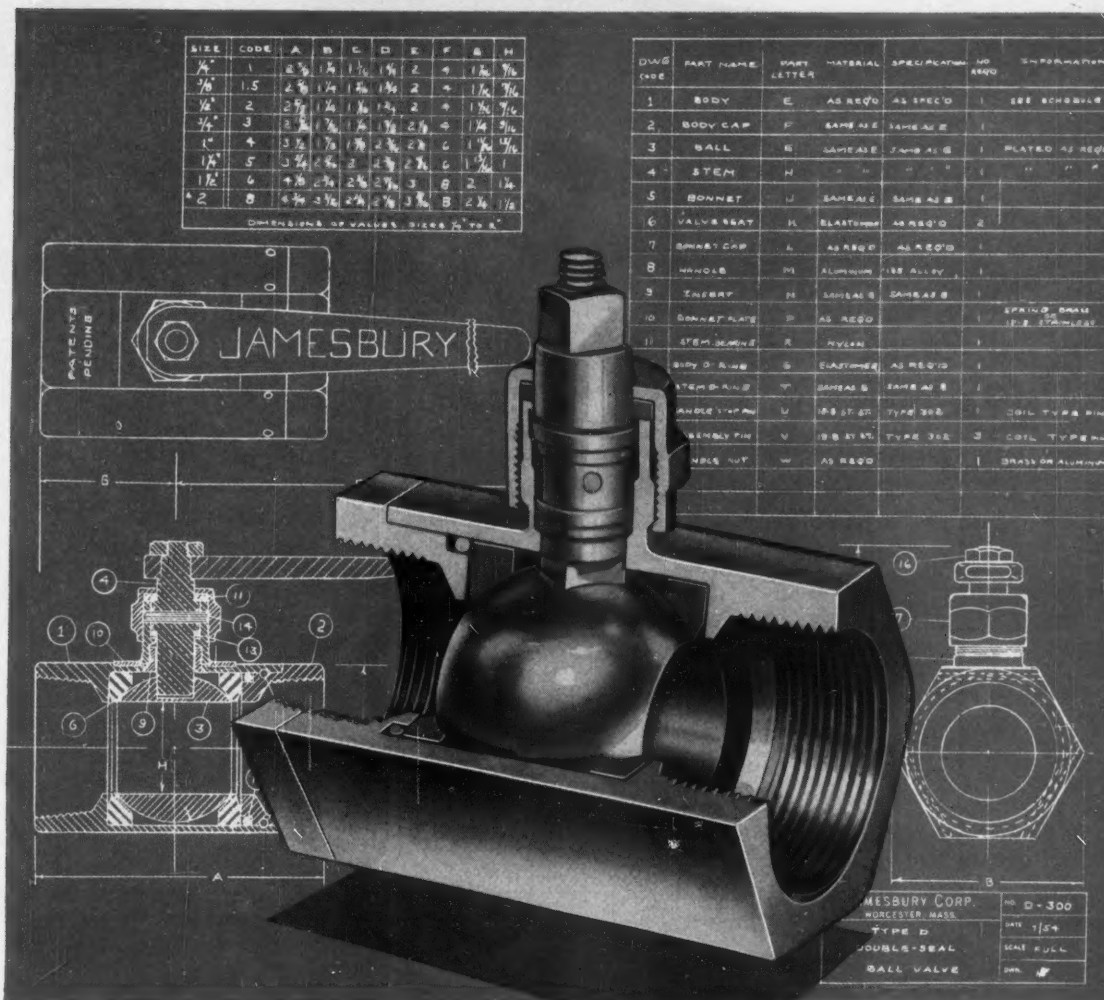
Buell's Low Resistance Fly Ash Collector combines top efficiency to meet present strictness, with low draft loss for natural or mechanical installations.

GET ALL THE FACTS
Write to:
Buell Engineering Company,
Dept. 12-F, 70 Pine Street,
New York 5, New York

buell®

MECHANICAL ELECTRICAL *Experts at delivering Extra Efficiency in* **DUST COLLECTION SYSTEMS**

New, all-stainless double-seal ball valve. Its manufacturer, JAMESBURY CORPORATION, Worcester, Mass., stresses its straight-line flow and elimination of practically all maintenance.



STAINLESS means corrosion-resistance in new double-seal ball valve...

The *all-stainless* construction of this new-type, double-seal ball valve means exceptional resistance to corrosion, erosion and abrasion. That's part of the reason why these Jamesbury valves are being used for chemical applications... processing of hot caustic solutions... even for the vacuum fields.

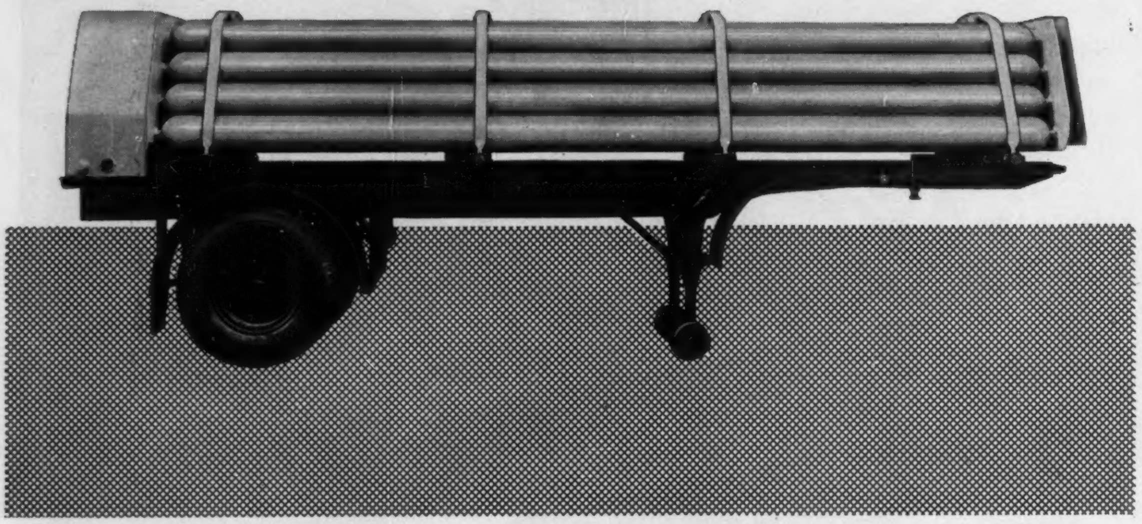
The valve differs from conventional globe or gate valves in that its operation depends upon a stainless steel ball, sealed with a plastic or rubber ring on both sides. All of the valve, including the ball, is machined from Crucible stainless bar stock, type 303 or 316.

Stainless may be the answer for your product, too. Why not let a Crucible engineer give you the facts concerning its most profitable use? *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Is this the answer to your gas transportation and storage problem?



Taylor-Wharton **GAS TRANSPORTS** are a practical solution to the problem of transporting and storing large quantities of compressed gases.

Oil refineries use them for hydrogen and nitrogen in starting the Reforming process. Chemical, electronics and food processing companies which have their own gas generating equipment use them for inter-plant distribution of gases. They also find gas transports excellent as a flexible means of temporary storage.

The advantages of Taylor-Wharton Gas Transports are especially notable with the lighter gases which are not easily liquefied, such as hydrogen and helium. They are also used for oxygen, nitrogen, boron trifluoride, ethylene and other industrial gases.

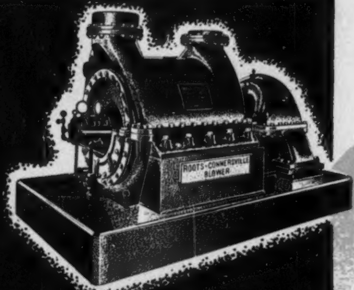
In some cases the gas transports are used instead of large permanent storage installations, *for a substantially smaller investment and with greater flexibility in use.*

The tubes are made in one of our plants to ICC-3A 2400 specifications. After fabrication they are completely heat-treated. The trailers are specially constructed for use with these transports. They are available in single and double axle models, 30 or 38 tube capacities.

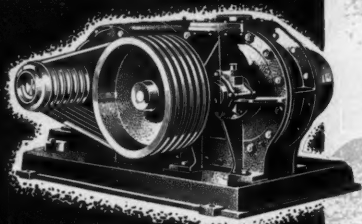
How can they serve you? Describe your gas transport and storage requirements and we will advise you.

Taylor-Wharton Co.
Division of
Harsco Corporation
HARRISBURG 3, PA. EASTON, PA.

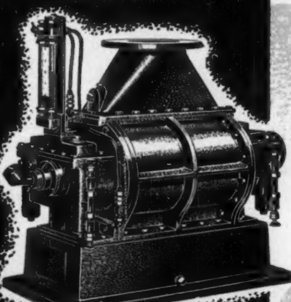
More than a century in Harrisburg



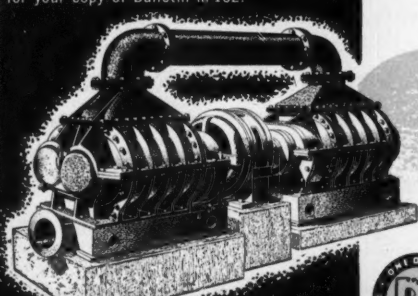
CENTRIFUGAL or Rotary Positive Blowers and Exhausters can move from 5 cfm to 100,000 cfm of air for many diversified needs. For complete details, send for Bulletins 120-B-14, AF-154 and RB-154.



GAS PUMPS can be applied to many industrial uses where from 5 cfm to 50,000 cfm are needed. Send for Bulletins 31-B-17 and 32-33-B-13 for full information.



METERS measure gas up to 1,000,000 cfh or as little as 4,000 cfh with constant accuracy. For specifications and capacity tables, send for your copy of Bulletin M-152.



VACUUM PUMPS with exceptionally low operating cost range in capacity from 500 cfm to 13,000 cfm, and up to 24" Hg vacuum. Complete information in Bulletin 50-B-13.

Production roadblocks avoided by ingenious use of air or gas

Alert industrial engineers and designers are finding new ways to put gas and air to work more effectively. They take delays out of industrial processing and improve quality. They add new utility to devices and appliances for commercial and home use.

...in many different applications

they are utilizing the many advantages of Roots-Connersville equipment. They move large or small volumes of air and gas with Blowers, Exhausters and Gas Pumps . . . produce vacuums . . . meter gas for proportioning or other measuring needs . . . protect plants against fire and explosion with Inert Gas Generators. Solutions of specific problems are often solved faster and better when

...assisted by Roots-Connersville ideas

These are the result of more than 100 years of knowledge and are available to any user of gas or air, or equipment builders who need them. If you have a product or a process which might be improved by our mutual effort, we'll gladly work with you.

Just address:

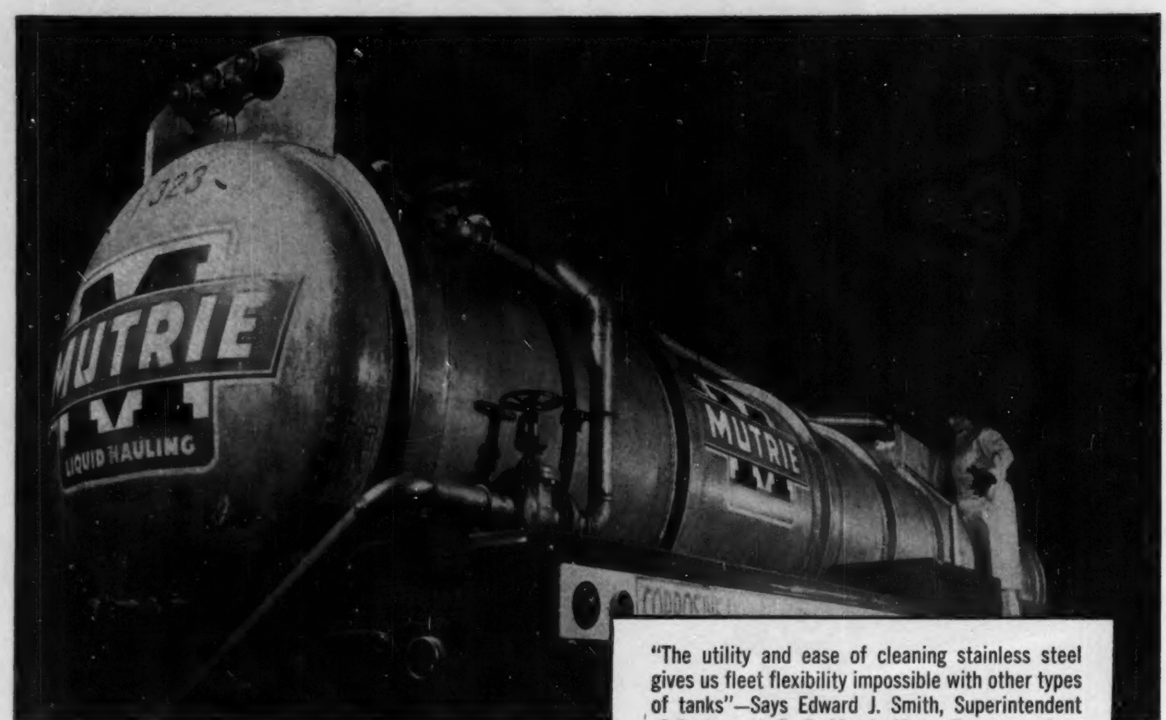
Product Development Manager, Roots-Connersville Blower Division
656 Illinois Avenue, Connersville, Indiana

ONE OF THE DRESSER INDUSTRIES

ROOTS-CONNERSVILLE BLOWER

ROOTS SINCE 1854 CONNERSVILLE

A DIVISION OF DRESSER INDUSTRIES, INC.



"The utility and ease of cleaning stainless steel gives us fleet flexibility impossible with other types of tanks"—Says Edward J. Smith, Superintendent of Equipment, P. B. Mutrie Motor Transport, Inc., Waltham, Massachusetts.

Versatility of Stainless Tank Trucks
Cuts Costs for Shipper

"Our 20 years' experience in hauling more than 400 different chemicals has shown us we get real versatility from our stainless steel tanks. For example, a truck can be taken off an acid haul, washed up and shifted to phenol or another chemical.

"With stainless tank trucks we can be sure of corrosion resistance, longer tank life and reduced maintenance. And the hard, smooth surface of stainless not only prevents contamination but cuts down off-the-road cleaning time."

In addition, stainless trucks enable Mutrie to haul more overhead-reducing return loads and, in compartmented tanks, a much greater variety of less-than-tank-load shipments.

You can put all these cost-cutting advantages of stainless steel tank trucks to work for you, whether you operate your own fleet or hire a carrier. From the many standard and special grades of stainless produced by Armco, a major supplier to tank manufacturers, you can specify the one that meets your requirements most economically.

Write us at the address below for complete details.

ARMCO STEEL CORPORATION

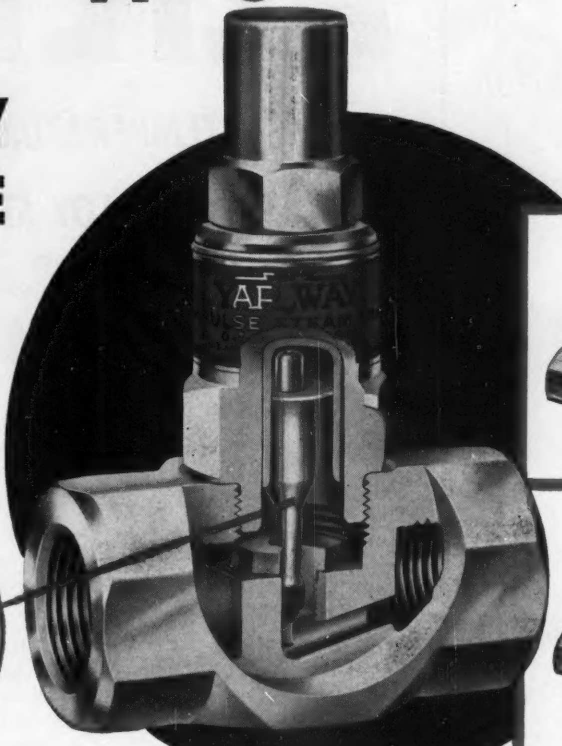
1596 CURTIS STREET, MIDDLETOWN, OHIO

SHEFFIELD STEEL DIVISION • ARMCO DRAINAGE & METAL PRODUCTS, INC. • THE ARMCO INTERNATIONAL CORPORATION

Offices in Chief Cities in U.S.A., Canada and Mexico, See Your Phone Book

the impulse that revolutionized steam trapping

YARWAY IMPULSE STEAM TRAP

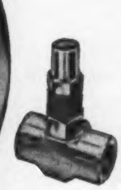


the only moving part

. . . a small stainless steel valve that literally floats on the condensate load. Gets equipment *hot in a hurry*—and *keeps it hot!*

SERIES 60 and 120

For all *normal* trap requirements, pressures to 400 and 600 psi.



½″ No. 20-A

For *light loads* on tracer lines, steam mains, small presses, etc.

SERIES 40

For *heavy loads* requiring extra high capacity steam traps.

INTEGRAL-STRAINER HIGH PRESSURE TRAP

For high pressures, high temperatures. (Flanged or welding connections.)

Twenty years ago YARWAY applied a unique theory of thermodynamics to steam traps—and gave industry the amazing YARWAY Impulse Steam Trap.

Today — over a million YARWAY Impulse Steam Traps later — advantages like the following continue to convert new users, and convince old users to standardize on the YARWAY Impulse:

- **QUICK HEAT-UP AND EVEN TEMPERATURES OF EQUIPMENT**
- **GOOD FOR ALL PRESSURES WITHOUT CHANGE OF VALVE OR SEAT**
- **SMALL SIZE—LIGHT WEIGHT**
- **ONLY ONE MOVING PART**
- **STAINLESS STEEL—minimum maintenance**
- **WON'T FREEZE UP**
- **A COMPLETE LINE of sizes and types for every requirement**
- **IMMEDIATELY AVAILABLE from 270 local Industrial Distributors**

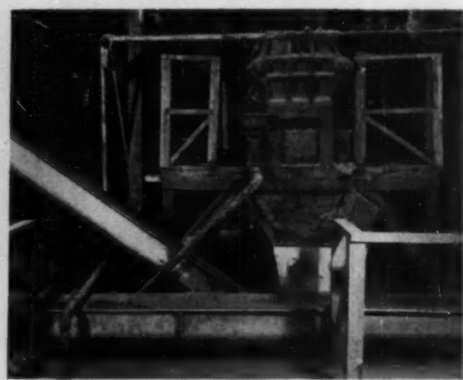
For free Trap Selector, or 24 page Bulletin, write

YARNALL-WARING COMPANY
137 Mermaid Avenue, Philadelphia 18, Pa.

YARWAY IMPULSE® STEAM TRAP

OVER 1,000,000 YARWAY IMPULSE STEAM TRAPS USED

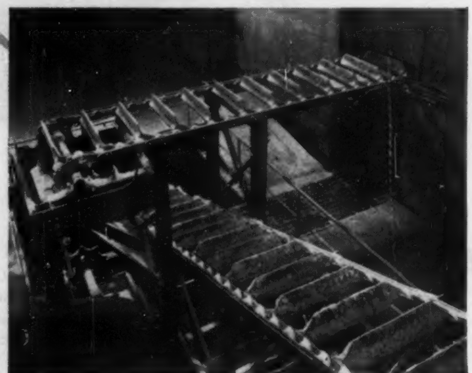
by conveyor belts



by spiral conveyors

If you move materials

by bucket elevators



by scraper conveyors

JEFFREY offers you

equipment incorporating the know-how gained in three-quarters of a century of studying and solving material-handling problems. Today, in thousands of plants throughout the world, Jeffrey conveying equipment is depended upon to maintain high production schedules, lighten the burden of labor and reduce operating costs.

Write for Catalog 860 describing Jeffrey material-handling and processing equipment. For high quality parts matching those originally installed on your equipment, get in touch with a nearby Jeffrey distributor or The Jeffrey Manufacturing Company, Columbus 16, Ohio.

JEFFREY

CONVEYING • PROCESSING • MINING EQUIPMENT
TRANSMISSION MACHINERY • CONTRACT MANUFACTURING

SAVE ON TOWER MAINTENANCE

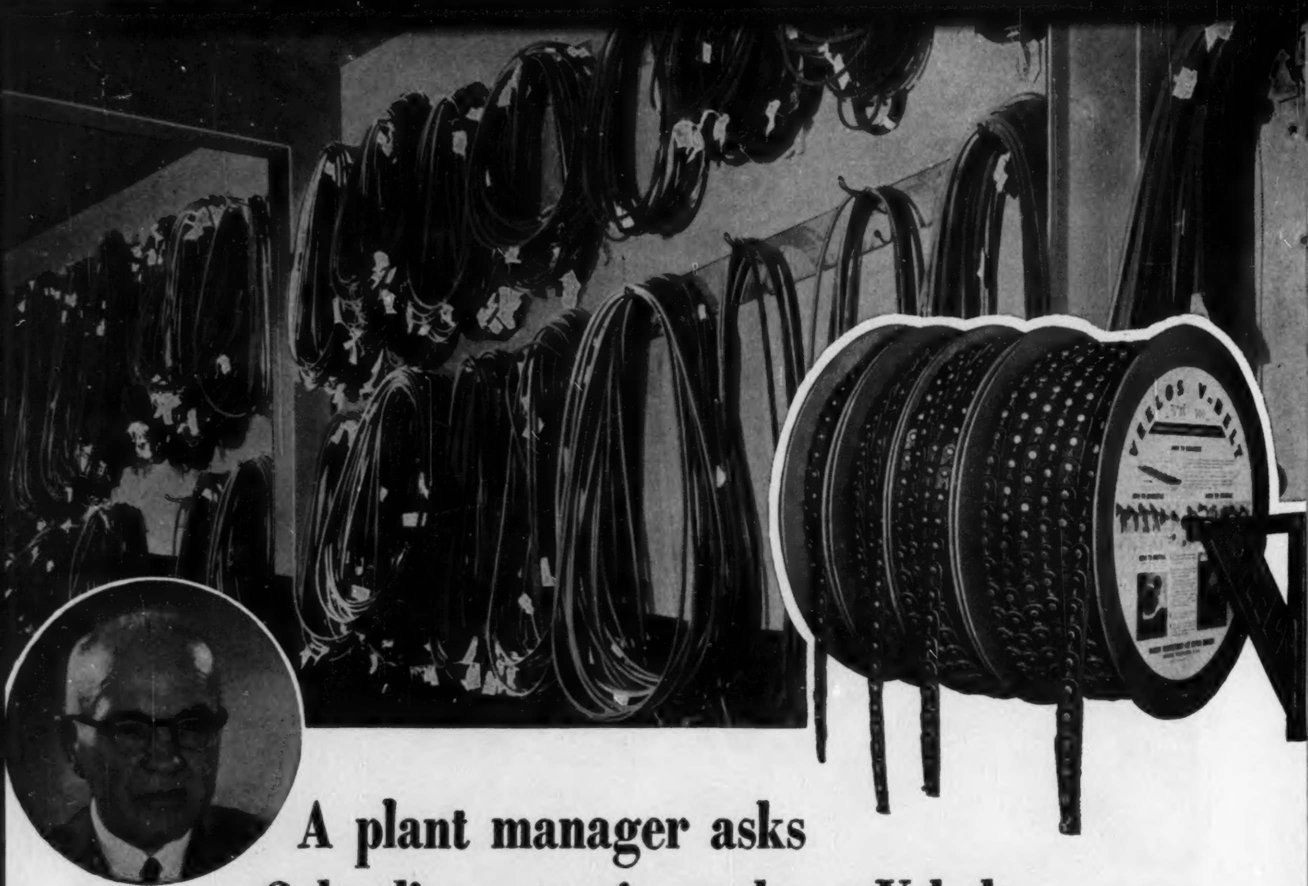
PACK WITH LAPP PORCELAIN RASCHIG RINGS

Lapp raschig rings are smooth, completely vitrified, strictly non-porous and iron free. They are chemically inert to acids of all concentrations (except hydrofluoric); there can be no crumbling from capillary pressures nor absorption of liquids to contaminate later processing. This combination of characteristics assures an indefinite life chemically. Physically, Lapp raschig rings are tougher against damage from handling and tower operation than other ceramic rings or other packing shapes.

Lapp customers report longer continuous service and greater purity of product from their Lapp packed towers . . . with greatly reduced maintenance costs.

WRITE for our bulletin describing the characteristics of Lapp Chemical Porcelain. See how you can save with a trouble-free system of Lapp Porcelain. Lapp Insulator Co., Inc., Process Equipment Division, 802 Wendell St., Le Roy, New York.

Lapp
CHEMICAL PORCELAIN



A plant manager asks 3 leading questions about V-belts

1 "I stock 85 different sized sets of belts—how can Veelos help me?"

With *four* 100′ reels of Veelos (O, A, B, C widths) you can replace as many as 316 different sizes of endless belts—and store your Veelos in *inches of space!* Veelos cuts your inventory to a minimum. No obsolescence or deterioration, no worries about specific sizes. With Veelos, your storage and inventory problems are licked!

2 "How does Veelos cut installation and down-time?"

Veelos is an *adjustable belt.* With Veelos, there's no tearing down outboard bearings, no resetting, tilting or moving motors to make belt replacement or repairs! And you don't have to replace a complete matched set because of one loose belt—Veelos belts adjust to any length, can be altered by adding or removing links!

3 "How do I eliminate costly belt vibration?"

Install Veelos in place of ordinary belts! Veelos belts are absolutely uniform; every stud and link is identical; every foot of the reel is identical and uniform; they're perfectly balanced. Your Veelos salesman can easily prove to you with a Veelos Vibration Analyzer (tested against any V-belt you might now be using) that Veelos *cuts vibration up to 90%!*

VEELOS® THE BALANCED LINK V-BELT

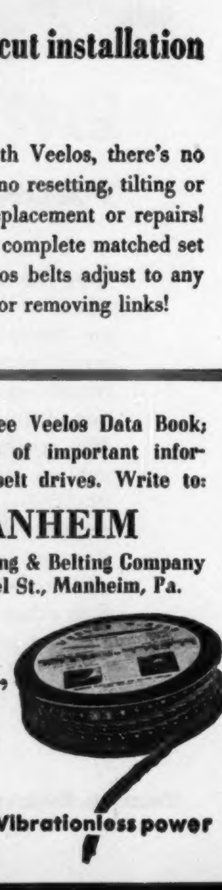
Veelos is known as Veelink outside U.S.A.

Get your free Veelos Data Book; many pages of important information on belt drives. Write to:

MANHEIM

Manufacturing & Belting Company
110 Stiegel St., Manheim, Pa.

"Industrial Belt Specialists Since 1911"



Adjustable to any length • Adaptable to any drive • Balanced power • Constant power • Vibrationless power

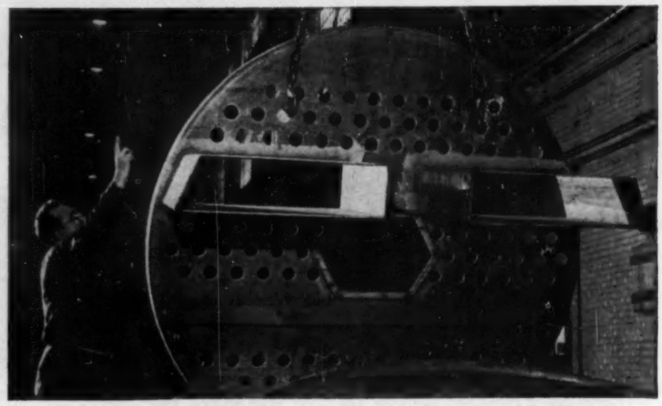
How's this for size?

It's two flatcars long and 9 ft in diameter. Weighing 125½ tons, this depropanizer tower is the heaviest and most complex of the 56 vessels we're fabricating for an East Coast refinery.

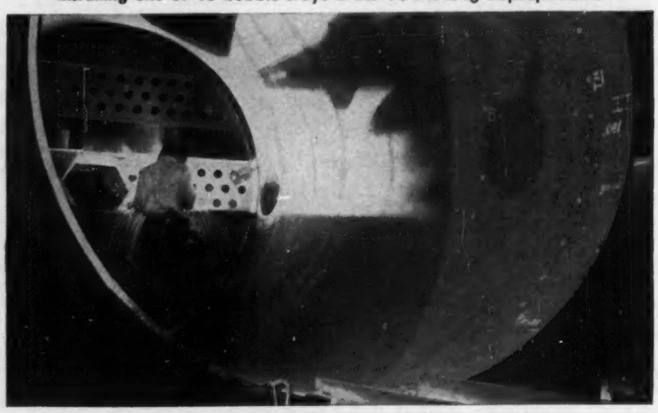
The vessel's 104-ft overall length includes a 12-ft skirt. The shell is 1⅛ in. thick. After welding in accordance with ASME 1952 code the tower was completely X-rayed and stress-relieved.

Chief reasons for the vessel's unusual weight and complexity are forty flanged bubble trays, equipped with bubble caps and downcomers. They were made from ⅜-in. plate and weigh 1445 lbs each. Fabricating and installing them called for some mighty skillful workmanship.

We've been fabricating petroleum and chemical towers and vessels for a good many years. If you have a job in mind, we suggest that you talk it over with us. Please get in touch with the Bethlehem sales office most convenient to you.



Installing one of 40 bubble trays in the 104-ft-long depropanizer.



BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

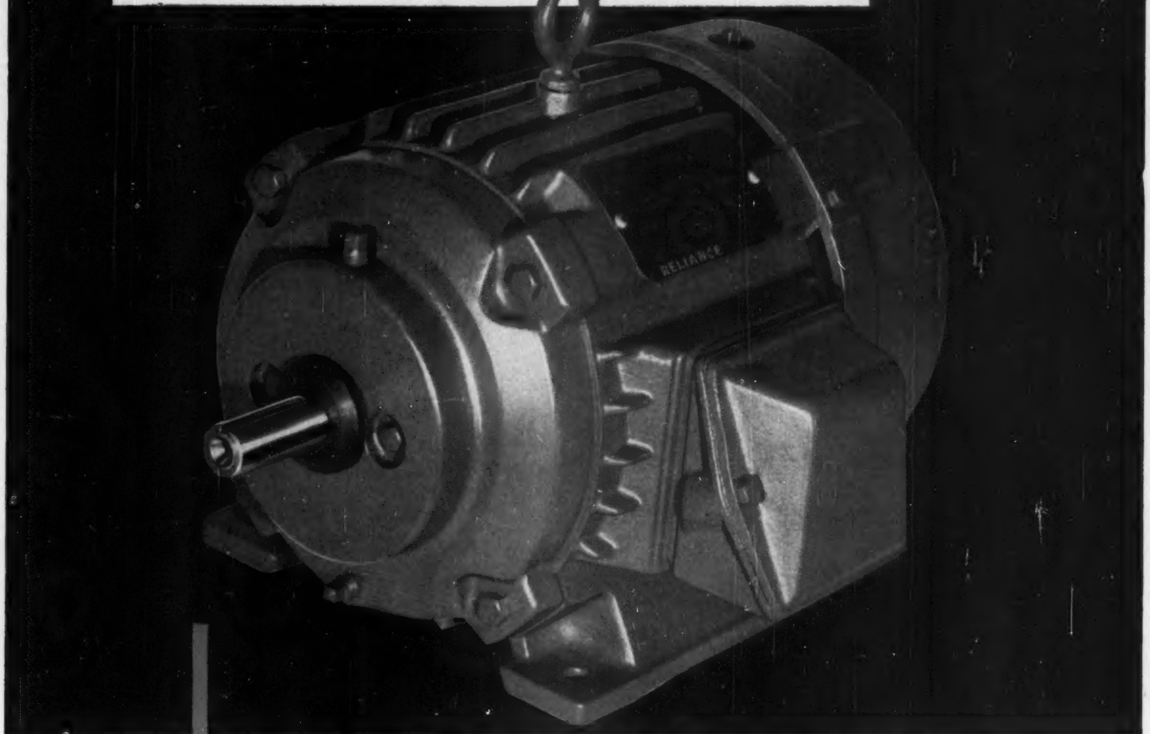
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
***Export Distributor:* Bethlehem Steel Export Corporation**

BETHLEHEM STEEL

BETHLEHEM STEEL

Not Just CORROSION-RESISTANT

BUT CORROSION-PROOF



Corrosion resistance is not enough to stop acids or alkalies from chewing up a motor in a hurry. That is why the wise engineer selects Reliance Corrosion-Proof Motors for corrosive service.

These motors are built to withstand the onslaught of destructive chemicals for years. Housings are made of virtually indestructible cast iron. Exterior contours are designed to slough off liquids—no nooks and crannies to retain corrosive elements. Enclosures are sealed to prevent any leakage . . . Metermatic lubrication systems provide complete protection against burned out bearings and contaminated lubricants.

Anyway you look at them, Reliance Corrosion-Proof Motors can take it—and you're not limited in the choice of motors either. A complete line of a-c. motors, 1 thru 300 hp., is available in all mountings, frequencies and voltages.

Why not call your Reliance representative today and get all the details.

B-1505

RELIANCE *Totally-Protected* MOTORS

RELIANCE ELECTRIC AND ENGINEERING CO.

Dept. 136A, Cleveland 10, Ohio • Canadian Division: Welland, Ontario

Sales Offices and Distributors in Principal Cities

ALLIS-CHALMERS
Sealed
Dry-Type
Transformers

Designed for the *Toughest Spot* In Your Plant

SAFE in any location regardless of Atmosphere or Moisture Conditions

Here's a transformer you can safely install anyplace without worries.

- **Fire or Explosion Hazard Eliminated** — Unit is hermetically sealed in inert-dry-nitrogen atmosphere.
- **Completely Protected**—Can be placed safely in flood areas, dirty and contaminated atmospheres, or in open work areas without vaults or barriers.
- **Insulation Life Increased** — Core and coil assembly is sealed in inert gas. Eliminating oxidation reduces thermal aging of insulation.
- **Maintenance Requirements Cut** — Elimination of cooling tubes and use of smooth tank surface reduce paint area as much as 60%. No internal liquids to maintain. All-welded construction. Number of gasketed openings reduced. Cleaning of core and coil eliminated. For these reasons, unit can be installed in hard-to-get-to places.
- **Low Installation Cost** — Unit is ready to be energized immediately upon delivery, after check to make certain no damage or leaks have occurred during shipment.

Allis-Chalmers transformers have an outstanding record of satisfying thousands of users all over the country. You can get the complete story on Allis-Chalmers sealed dry-type transformers from your local A-C office, or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin.

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

LIVE BETTER ELECTRICALLY

A-5035

These Speedomax recorders, teamed with Thermal Conductivity Analyzers on the synthesis unit (right), chart final yield (far left), and H_2-N_2 ratio before and after recycle gas enters feed stream.

L&N Analyzers Help The Atlantic Refining Co. Produce Maximum Ammonia Yield Economically

At The Atlantic Refining Company's modern ammonia plant in Philadelphia, peak performance depends on holding a precise hydrogen-nitrogen ratio to the converter, for maximum ammonia yield. A team of L&N Thermal Conductivity Analyzers with Speedomax® recorders handles the vital measuring jobs involved.

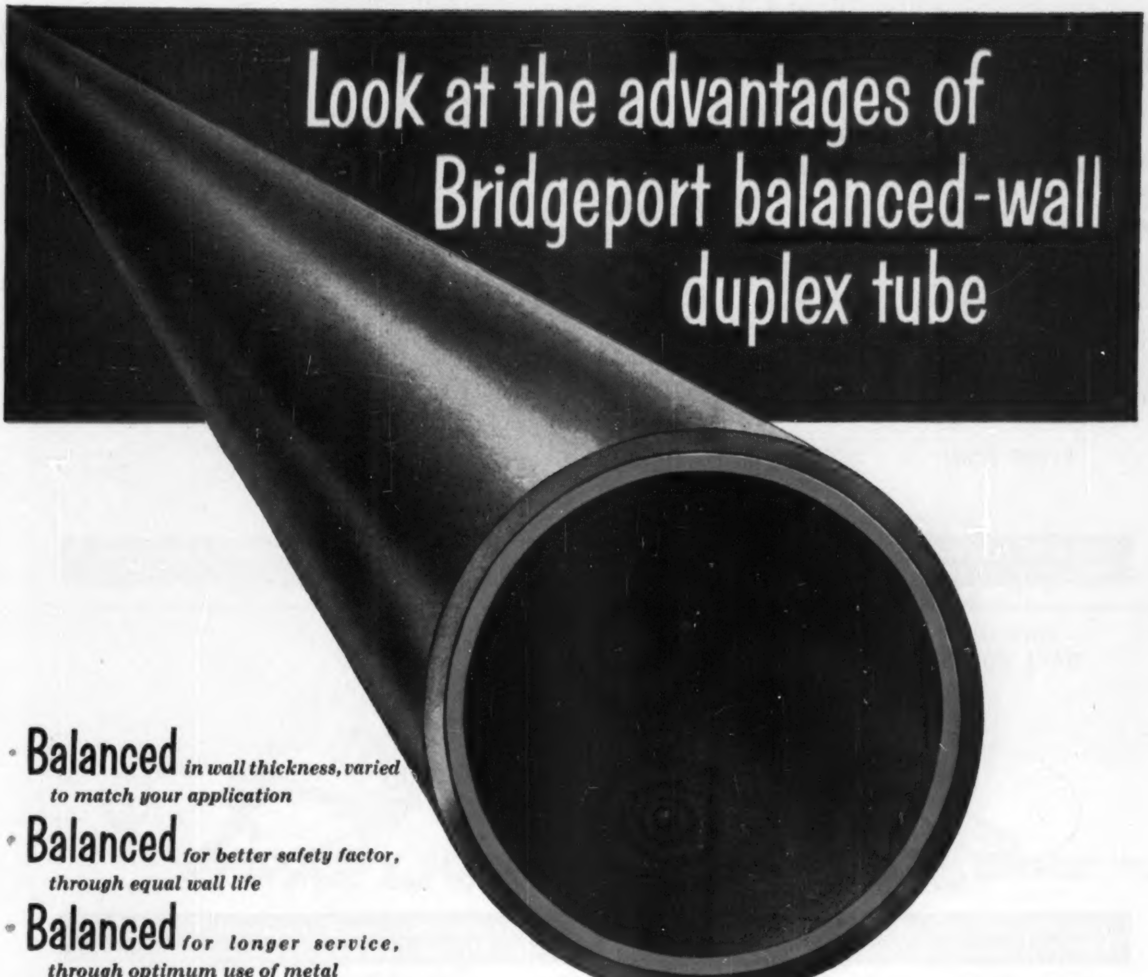
The H_2-N_2 ratio itself is so important that The Atlantic Refining Company operates two identical L&N Analyzers on the feed stream, one before and one after entry of recycle gas. These continuously record H_2 over a range of 65 to 85% while another Analyzer, calibrated 0 to 20% NH_3, records ammonia yield from the converter, and the amount returned in the recycled gas stream.

Feed hydrogen for the process is a by-product of The Atlantic Refining Company's design of catalytic reformer, known throughout the industry as a Catformer.

The Atlantic Refining Company's applications are typical of hundreds of successful jobs these recording and controlling L&N Analyzers are doing, not only in other ammonia synthesis plants, but on widely varied measurements throughout the process industries. For complete product data, write for Folder ND46-91(2). Or, to find how analytical control can benefit specific processes you have in mind, outline your problem for our engineers without obligation. Our address—Leeds & Northrup Co., 4916 Stenton Ave., Phila. 44, Pa.

LEEDS NORTHRUP
instruments *automatic controls • furnaces*

Look at the advantages of Bridgeport balanced-wall duplex tube



- **Balanced** *in wall thickness, varied to match your application*
- **Balanced** *for better safety factor, through equal wall life*
- **Balanced** *for longer service, through optimum use of metal*
- **Balanced** *in metal specification to resist different types of corrosion, inside and out*

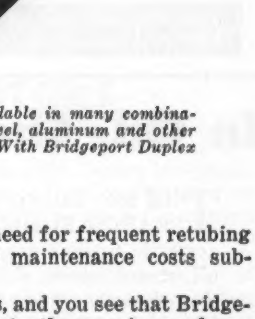
Bridgeport Duplex Tubes are available in many combinations of copper-base alloys with steel, aluminum and other metals. Lifetime Costs Are Lowest With Bridgeport Duplex Tubing.

Before specifying any heat-exchanger tubes, consider these facts: The job of each Bridgeport Duplex Tube is analyzed and gauges are calculated so that both inner and outer tubes will attain the same long life. The wall thickness of the component tubes in Duplex is varied to meet your specific application needs as influenced by temperature, pressure, corrosion rate on the inside and outside. You are assured a *balanced-wall* Duplex Tube, with improved safety factor, which makes practical use of every ounce of metal.

Another important benefit is the superior heat-transfer properties of Bridgeport Duplex Tube, achieved by a closer, cleaner bond on the interfaces. And, of course, by resisting different types of corrosion inside and out, they eliminate or reduce the need for frequent retubing and shutdowns, and reduce maintenance costs substantially.

Add up all these advantages, and you see that Bridgeport Duplex Tubes give consistently superior performance *and* lasting economy over a period of time. Remember, it's lifetime costs that count and Bridgeport Balanced-Wall Duplex Tubes assure lowest lifetime costs. Our Technical Service Department will be glad to recommend Duplex Tubes to match your individual service requirements.

Call your local Bridgeport Sales Office for complete information. Ask for Bridgeport's Duplex Tube Technical Bulletin.



Brass Bridgeport Co

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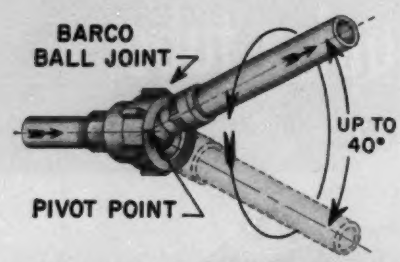
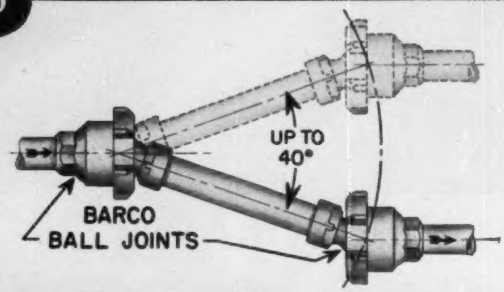
Barco Flexible Ball Joints

for solving piping problems MOVEMENT • ALIGNMENT • EXPANSION CONTRACTION • VIBRATION • SHOCK

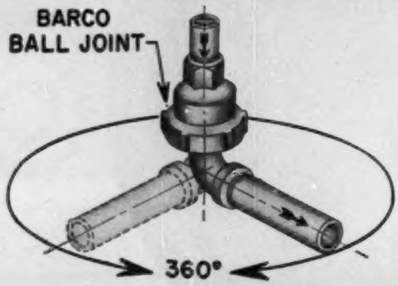
BARCO



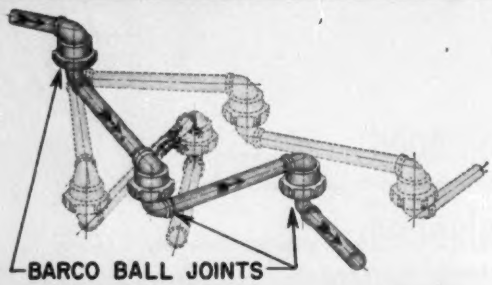
ONE JOINT—Provides for angular motion or positioning of piping in any plane. (Also see below.)



TWO JOINTS—This arrangement provides for piping alignment or simple flexible connection.



ONE JOINT—Allows for full 360° swivel or swing motion, in addition to angular movement shown above.



THREE (OR MORE) JOINTS—For complete flexibility. Any angle! Any radius! Any plane! Many arrangements possible.

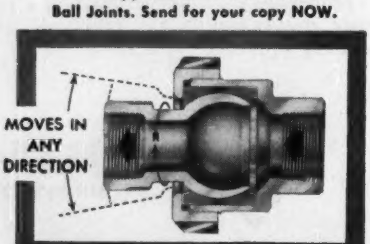
In Oil, Chemical, and Petrochemical Piping

THE four basic principles of motion illustrated above make the BARCO Flexible Ball Joint one of the most useful, most versatile fittings ever developed for piping conveying chemicals, oil, steam, water, air, and countless other fluids. *One joint often does the work of two or more ordinary swivel joints, because it moves in any direction!*

Metal pipe made flexible with Barco Flexible Ball Joints is practically indestructible. Long range planning calls for the permanence of this type of construction—*for freedom from maintenance and replacement, and SAFETY!*

There are many applications for Barco Flexible Ball Joints in industry: (1) To permit movement, (2) To accommodate expansion and contraction, (3) To provide for alignment, (4) To insulate against vibration and shock. For piping up to 12". Wide choice of styles and materials. *Let us give you the complete story.*

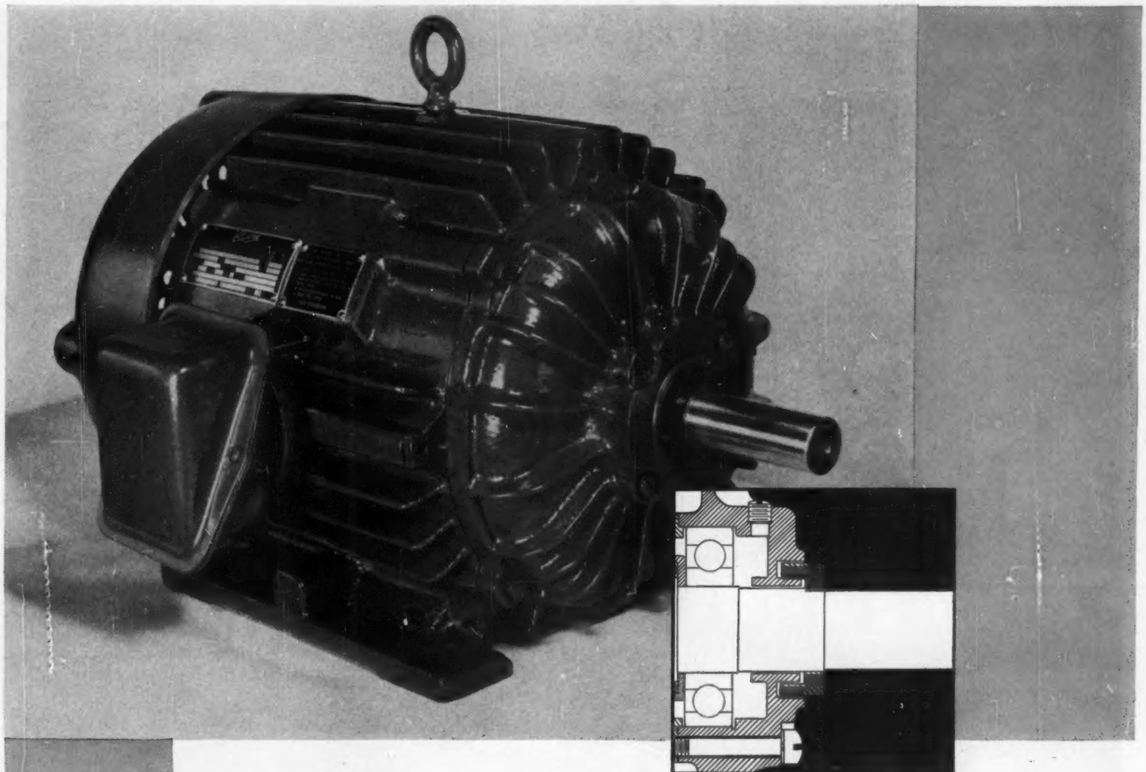
GET THE FACTS—New Catalog 215B is an interesting, illustrated handbook on the application of Barco Flexible Ball Joints. Send for your copy NOW.



BARCO *Manufacturing Co.*

516G Hough Street • Barrington, Illinois

THE ONLY TRULY COMPLETE LINE OF FLEXIBLE BALL, SWIVEL, SWING, AND REVOLVING JOINTS



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TOTALLY ENCLOSED FAN COOLED MOTORS

When motor maintenance goes down, production goes up. Century TEFC Motor *protects itself* from dust, grit, chemical fumes, moisture. Shaft openings at each end are labyrinth-sealed, and there is a precision clearance between metal seal and bearing bracket.

Outside, a hose or whisk broom quickly cleans it. External fan forces jets of cooling air across the frame. Inside, vital motor parts are completely sealed off from injurious atmosphere. Factory lubrication of bearings is adequate for several years' service under normal conditions; however, whenever required bearings may be relubricated through grease plugs.

For full facts on your specific application, call the Century District Office or Authorized Distributor nearest you.

CENTURY sets the pace . . . building TEFC Motors for 25 years

CE-66

Performance-Rated © MOTORS 1/20 to 400 H.P.

CENTURY ELECTRIC COMPANY

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When the pressure's on for pressure vessels

Specialized production techniques and the skill of Newport News craftsmen operating vast fabricating shops team up to deliver trainloads of pressure vessels on schedule.

When it comes to turning out process equipment, Newport News has the facilities and experience. So get a bid from Newport News on your present or future projects. Get the benefit of plant methods developed by specialists producing pressure vessels, vacuum tanks, towers, reactors, weldments and sub-assemblies.

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Newport News

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Bendix General Purpose Computers are saving users untold years of engineering time. This **time-saved** factor, as in the cam designs described here, is the common denominator which makes the Bendix Computer so effective in every line of work where complex mathematical problems must be solved.

PROBLEM: To design 14 cams for control mechanisms. The radii (approximately 1400) of each cam were to be computed at even ¼° points with the radii accurate to the nearest ten thousandths of an inch.

CONCLUSION: (Directly quoted from the Bendix user) "Figuring conservatively, several hundreds of thousands of equations were solved in the 40 hours needed to run the cams on the Bendix G-15 Computer. It has been estimated that it would take an engineer about three years to do the same work and possibly a fourth year to find his mistakes. Computing with the G-15 not only cut the cost of the task; but, often more important, freed engineers for other work and enabled us to get the units on the market ahead of competitors."

The Bendix G-15 is a high speed, large capacity digital computer. Because of its low cost, users have found that the Bendix Computer can be written off in 3 years or less with the savings it can effect.

Bendix Computer

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Tell us how we can economically use the Bendix Computer in our engineering, research and control functions.

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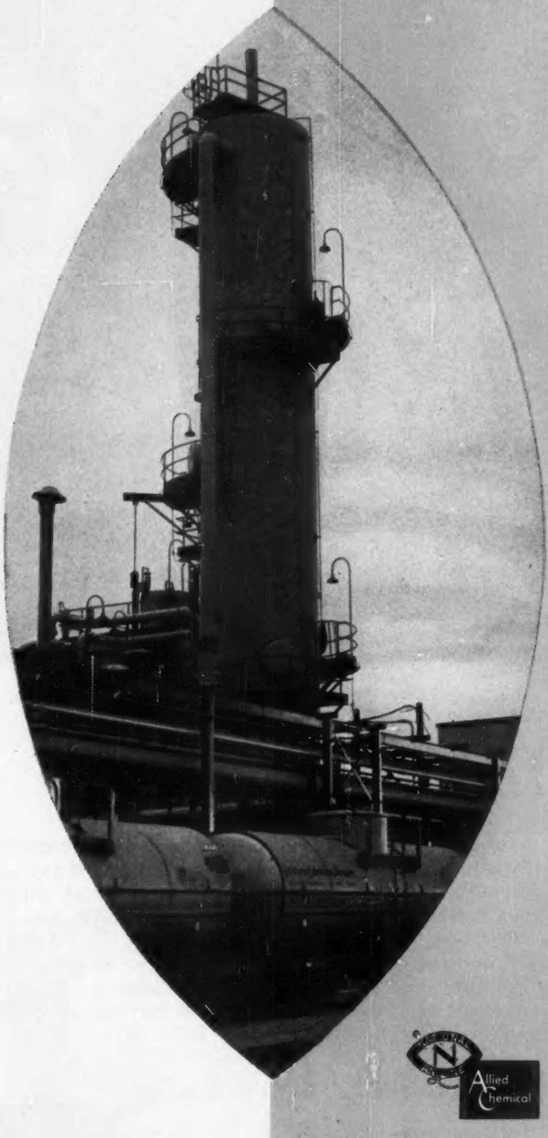

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This comprehensive 8-page technical bulletin on National Adipic Acid gives physical and chemical properties; principal reactions of the carboxyl and alpha methylene groups; solubility curve, and suggested uses with copious literature references.

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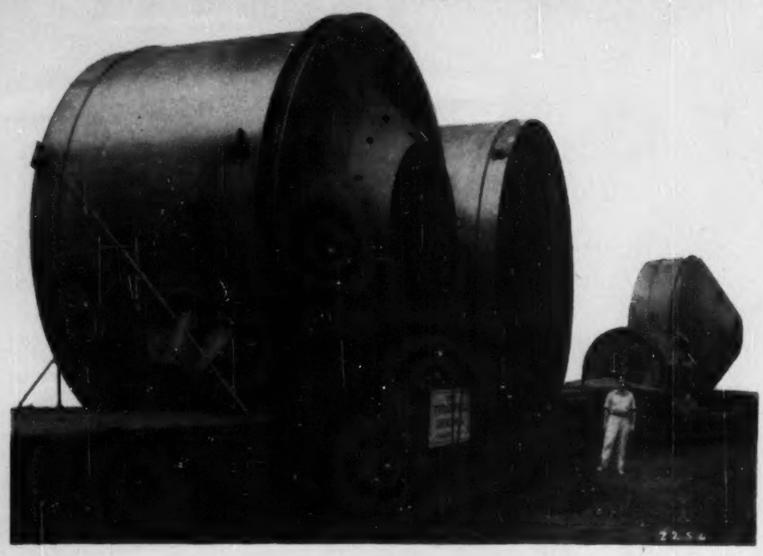
to YOUR *Specifications*



1. Vacuum Distillation Units

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Separators
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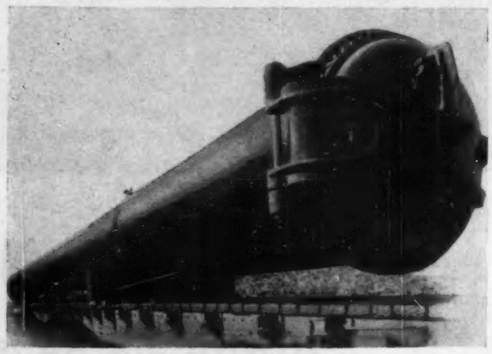
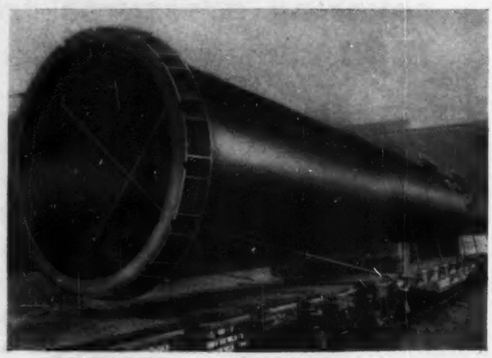


2. Treating Cylinder and Vulcanizer

• The Treadwell organization has been closely identified with the Chemical Processing Industry through nearly 50 years of growth and progress. During this period Treadwell has engineered and fabricated virtually every type of process equipment in use by the far-flung chemical process field. Not restricting itself to "stock" or standard items, the manifold facilities and versatile know-how of Treadwell's organization can blend to produce the most exacting and difficult custom equipment.

These illustrations show a few of the numerous types of equipment manufactured by Treadwell for the Chemical Process Industry.

Treadwell engineers are available to assist you in design; and with our large, modern facilities, we can meet your most difficult machining and fabrication requirements efficiently and economically.



3. Stripping Tower

FOR COMPLETE DATA ON TREADWELL FACILITIES —ASK FOR BULLETIN P-55.

TREADWELL CONSTRUCTION COMPANY

PLANT & MAIN OFFICE • BOX 20 • MIDLAND, PA.

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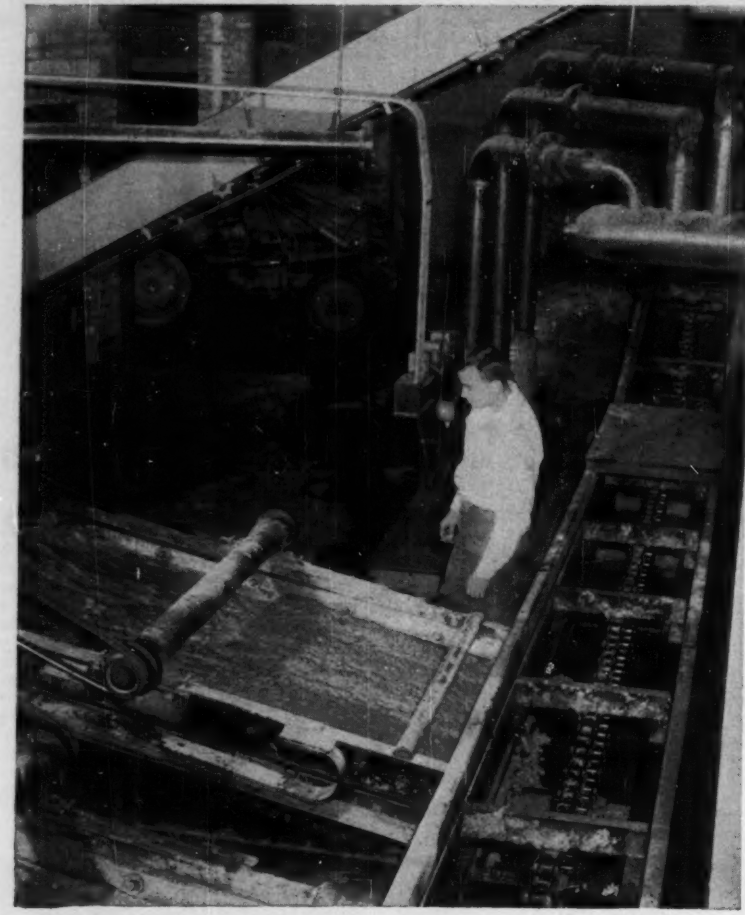
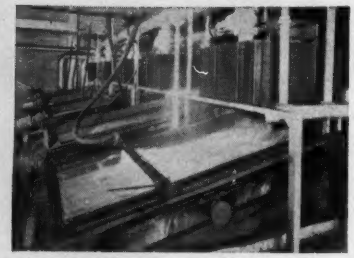
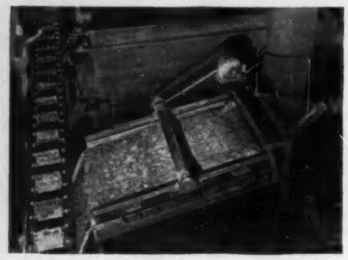


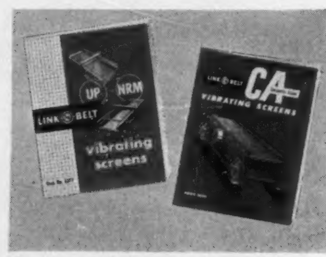
CHEMICAL WASTES can be profitable. These Link-Belt Liquid Vibrating Screens, combined with a Thru-Clean Bar Screen, Straightline Grit Collector and flight conveyor, remove solid wastes for later sale as feed and fertilizer.



Five liquid screens are used to reclaim dewatered pulp and clarified water for re-use.



High-energy vibrators keep meshes open, assure low-cost removal of solids from waste water.



Books 2377 and 2554 describe the complete line of Link-Belt vibrating screens for chemical plants.

Waste pays its way

when Link-Belt Liquid Vibrating Screens reclaim by-products and help put a halt to stream pollution

EVERY day, thousands of dollars literally go down the drain in industrial "waste." In many cases, an analysis by a Link-Belt engineer might show how it could be salvaged at a profit with Link-Belt Liquid Vibrating Screens.

Working on a principle of high-frequency, low-amplitude vibration, these screens can be adjusted for most effective separation. Solids are retained, liquids are passed—stream pollution is reduced.

Whatever your screening problem, there is a Link-Belt vibrating screen to do the job. Smooth, powerful vibrating action prevents plugging or blinding, assures fast, accurate separation. Adjustable amplitude permits screening a variety of materials . . . from sticky ores to soft, dry feeds. For all the facts, write or contact your nearest Link-Belt office.

LINK-BELT

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14,142

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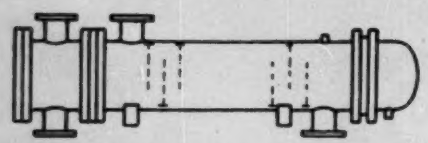
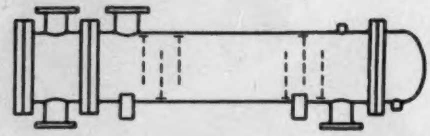
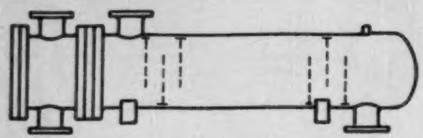


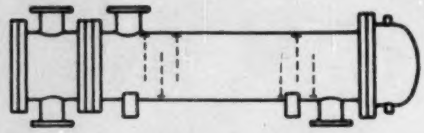
Type SG straight tube, outside packed lantern gland design. Eliminates undetected fluid inter-leakage.



Type S pull-through floating head design. For condensing, heating services . . . easy maintenance.

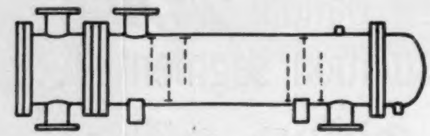


Type R U-tube design. Low cost construction, for non-fouling service.



Type ST conventional straight tube, split ring, floating assembly construction.

HOW YOU CAN SAVE WITH Whitlock Standardized Heat Exchangers!



Straight tube, fixed tube sheet design. Types V and V-1 — for easy mechanical cleaning.

SAVE WORK . . . "prints for approval" can be supplied quickly for piping and other layouts.

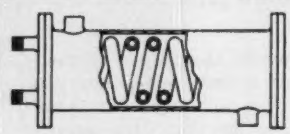
SAVE ENGINEERING COSTS . . . our engineers will help you select a standard design suited to your requirements.

SAVE DELIVERY TIME . . . many units can be manufactured promptly from stock materials and sub-assemblies. Also, completed units are often in stock for immediate shipment.

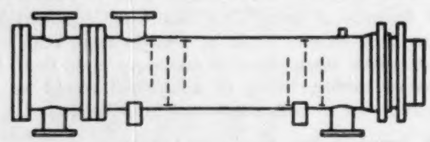
SAVE ON REPAIRS . . . readily available duplicate parts simplify emergency repairs . . . reduce downtime.

SAVE ON FIRST COSTS . . . our long manufacturing experience plus quantity produced sub-assemblies and quantity purchasing of materials reduce the unit cost of Whitlock Standard Exchangers. These savings are reflected in our current prices.

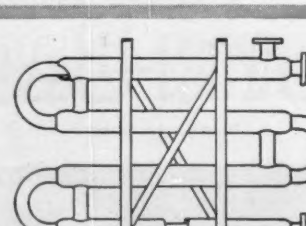
Compare costs . . . compare *savings*. It pays to consider Whitlock Standard Exchangers *first*. Send for Bulletin 250. The Whitlock Manufacturing Co., 94 South St., West Hartford 10, Conn.



Type C coil type heat exchangers. For high tube side pressures.



Floating head heat exchangers. Type SO with outside packed head — no concealed, bolted and gasketed joints.



Double pipe heat exchangers. For counter-temperature flow conditions and low flow rates.

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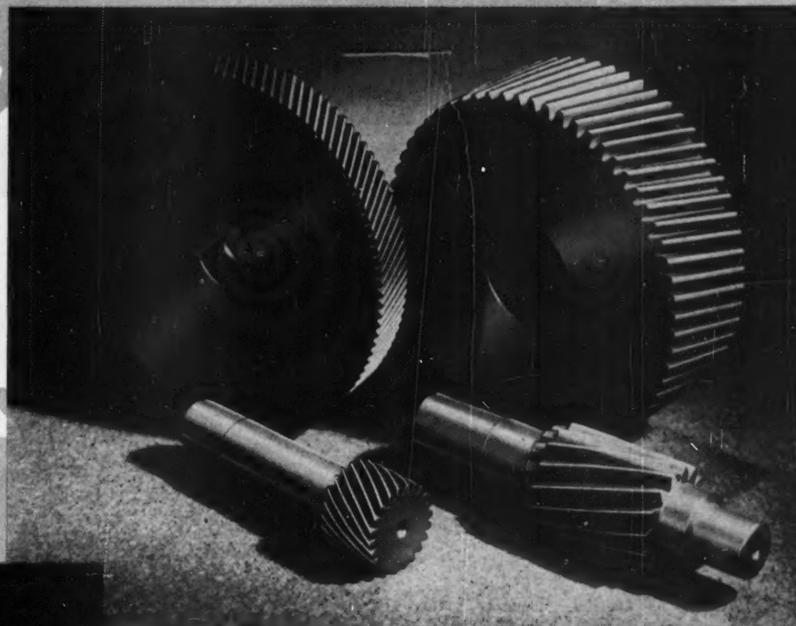
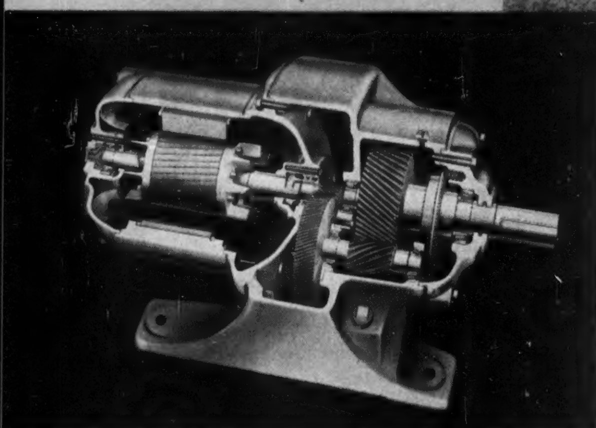
GEARS *match Motor Reliability*

Both Gearing and Motor of the **SYNCROGEAR** are "Custom-built" by **U. S.** to the same high quality





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Completely described and illustrated in our new 16-page full-color brochure. Learn about new techniques in gear making for gear motors. In addition to custom-engineered gears, U.S. Syncrogear motors incorporate many other advanced life-lengthening features, including: genuine pyramidal design; completely enclosed case; solid shank ever-tight pinion; friction-free oil seal; asbestos-protected windings; normalized castings and Lubriflush transverse lubrication.

U.S. MOTORS

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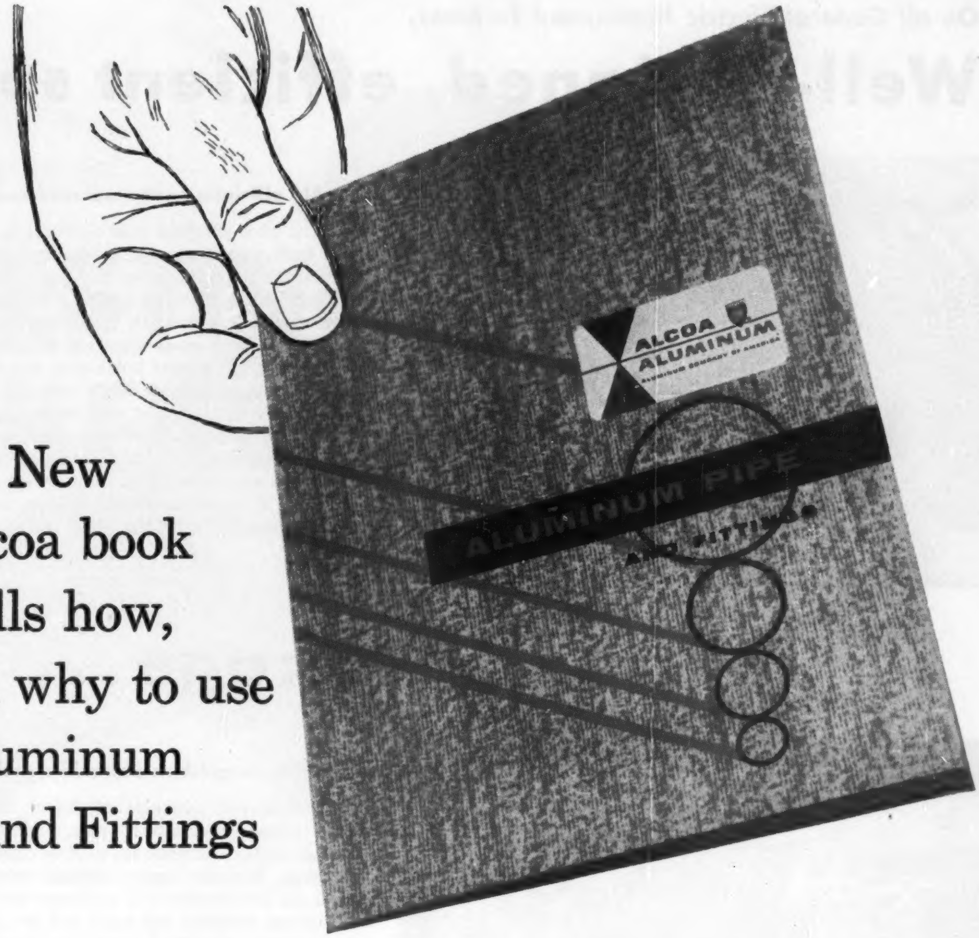

New Alcoa book tells how, where, why to use Aluminum Pipe and Fittings

ALCOA Aluminum Pipe is being used in more applications—solving more and more problems than ever before. That's because ALCOA Aluminum Pipe offers three important advantages: (1) Its low price makes it the least expensive material to use for special-purpose piping; (2) Its lightness makes it ideally suited for quick, economical installation; (3) Its durability keeps maintenance and replacement costs at rock bottom.

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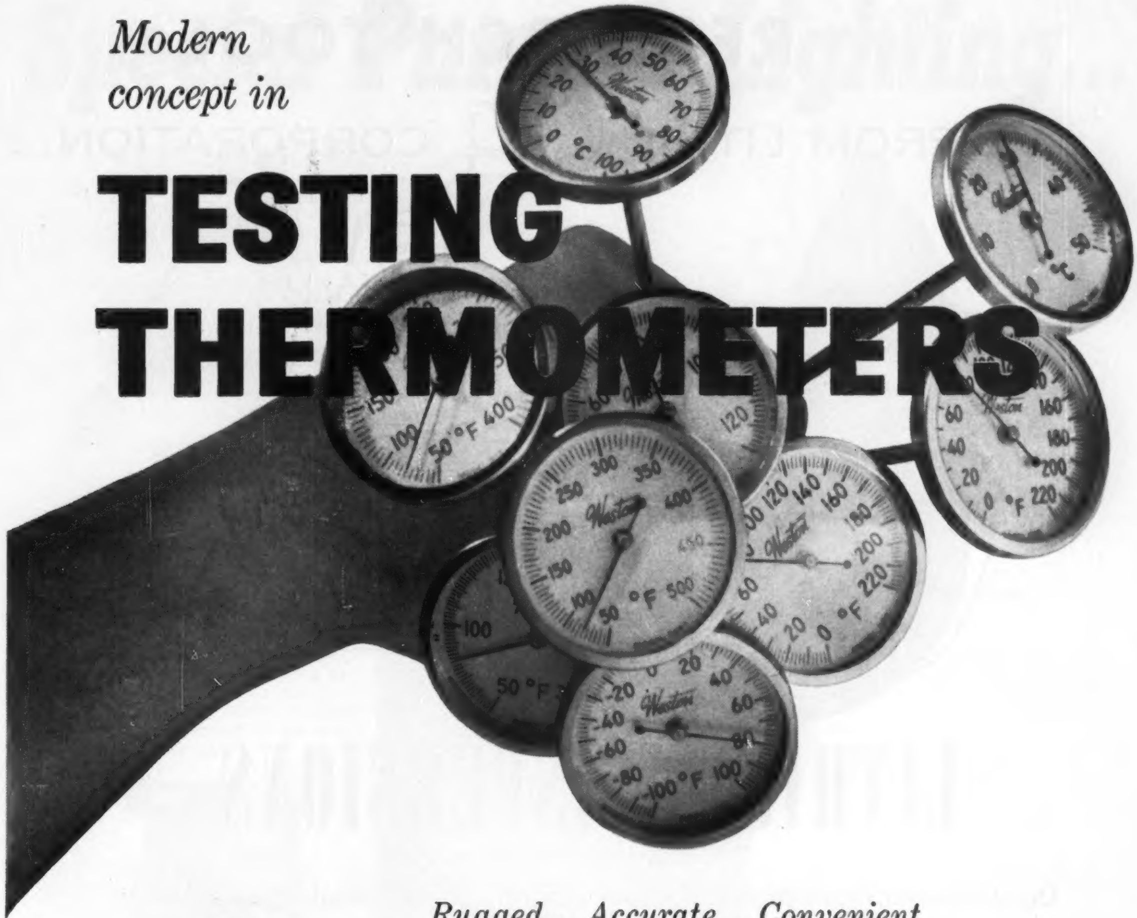
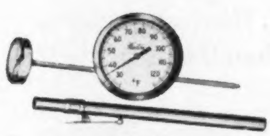
TESTING THERMOMETERS



Rugged... Accurate... Convenient for laboratory and equipment needs



Precision POCKET THERMOMETERS

Dials 1″ dia. – spike stem 5″ long – 18-8 stainless steel construction – ranges as low as –40F to high as +500F – accuracy ½ of 1% of thermometer range.

General Purpose THERMOMETERS

Dials 2″ dia. – 18-8 stainless steel construction – ranges as low as –100F to high as +1000F – accuracy 1% of range.

Model 2282 – standard stem length 8″ including hub.

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For laboratory needs, for production testing and inspection, for equipment mounting . . . wherever high sustained accuracy and quick response are essential . . . WESTON all-metal thermometers have been widely adopted because they are more convenient to use, and far more durable and economical. Cases and stems are of 18-8 stainless steel – standard stem length 8″ – 2″ to 24″ length available on order – dials 1¾″ dia. – ranges from low as –100F to high as +500F. Require only 2″ immersion in solids or liquids. Accuracy ½ of 1% of thermometer range. For the complete story, including data on all-metal thermometers for industrial use, write now for bulletin T-13. Weston Electrical Instrument Corporation, 614 Frelinghuysen Ave., Newark 5, N. J. A subsidiary of Daystrom, Incorporated.

WESTON *all-metal*

THERMOMETERS

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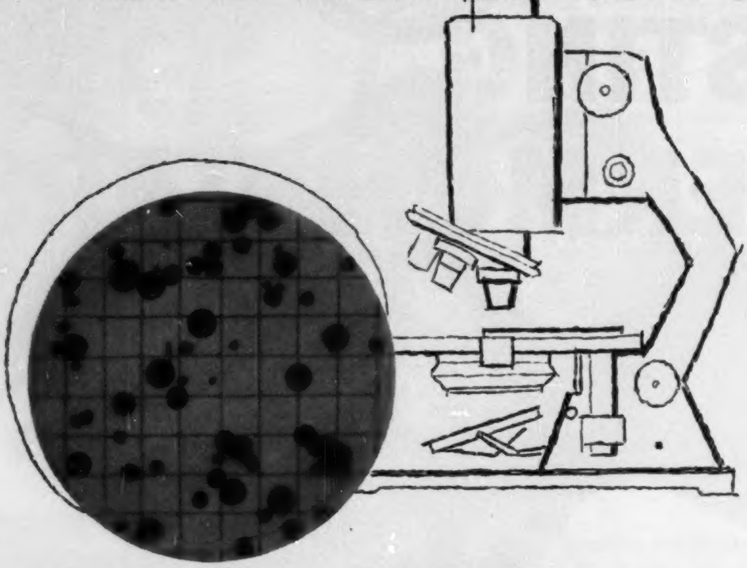

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Our successful development of dispersions of Lithium Metal offers industry still another research technique once considered impractical. Readily prepared, lithium dispersions prove more stable to air and moisture than the metal itself due to the coating of the dispersing medium.

In case you have a problem requiring the use of highly reactive Lithium Metal, Lithium Corporation's PR&D department is making available product data sheets describing the methods for laboratory preparation of these lithium metal dispersions in such dispersing mediums as mineral oil, petrolatum and wax. A request attached to your letterhead will bring you information on this new tool in lithium research.

... trends ahead in industrial applications for lithium

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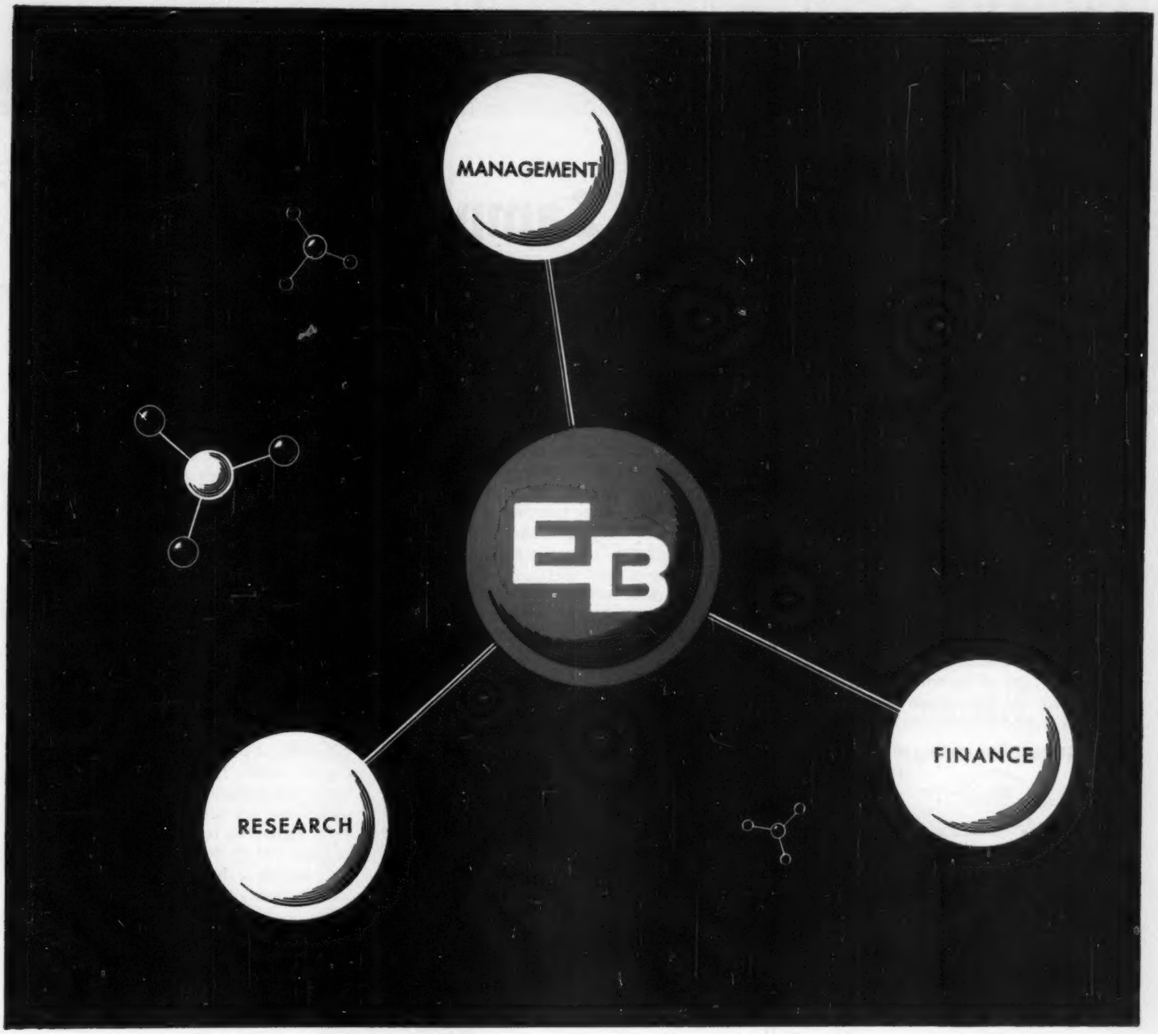


from these three . . . comes progress!

You are cordially invited to visit the Escambia Bay exhibit (Booth #1220) at the National Plastics Exposition, New York Coliseum, June 11-15, 1956.

A successful company, like a successful product, is the result of sound management, adequate financing, and intensive research. Escambia Bay Chemical Corporation—a new "element" in plastics raw materials—has applied these basic factors to their fullest in bringing nitrogen fertilizer materials on stream in a matter of months.

Progress is continuing rapidly with the construction of a 30 million pound polyvinyl chloride resin plant at the site near Pensacola, Florida, to be in production before the end of this year.

With emphasis on research and development, quality control, product uniformity and technical service, Escambia Bay has plans for the future in keeping with the progress made to date.

ESCAMBIA BAY CHEMICAL
CORPORATION
261 MADISON AVENUE • NEW YORK 16, N. Y.

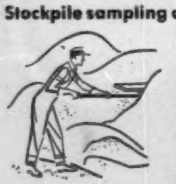
Using Salt Efficiently

by **INTERNATIONAL SALT COMPANY, INC.**—America's largest producer of salt

How to Sample Rock Salt for Screen or Chemical Analysis

Sampling bulk rock salt accurately is often a difficult problem. For when salt is stored in piles, coarser particles collect at the foot of the pile—while finer particles remain inside and at the top. A few handfuls of salt taken at random from the outside and bottom of such a pile almost always mean an inaccurate sample for analysis. Also, during transportation and handling, salt particles of different sizes tend to become segregated.

However, by following a few simple steps, you can easily obtain salt particles of a truly representative size range. This sample will then give accurate results in any type of screen or chemical analysis. Here are the modern sampling techniques approved for most plants where salt is used:



Stockpile sampling of bulk salt. Samples from either indoor or outdoor stockpiles should be taken at three separate points: at the top of the pile, at the base, and at one intermediate point. The sample taken at the intermediate point must come from deep within the pile. To prevent segregation of salt particles during this sampling procedure, a board should be pushed into the salt pile just above the point from which the sample is taken.

Sampling bulk salt in railroad cars or trucks. In sampling a boxcar load of salt, three trenches should first be made in the salt across the width of the car. The bottom of each trench should be at least 1 ft. below the surface of the salt, and approximately 1 ft. wide. Equal portions of salt can then be taken from nine equally spaced points along the bottom of each trench. Two of the nine points should be directly against the sides of the boxcar. Sampling in these trenches is best accomplished by pushing a shovel or sampling tube directly into the salt, and not by scraping horizontally.

The same general procedure may be used effectively to sample truckloads of rock salt.

Sampling between transport and storage. Rather than sample bulk salt in cars or in storage, many companies feel that more accurate samples can be taken during unloading—at some point in the handling process where a flowing stream of salt is accessible on all sides. The points at which salt leaves a head pulley or drops from a chute lip are two of the most desirable places for this type of sampling.

This "running sample" gives consistently excellent results, but it must meet the following conditions as closely as possible:

1. To obtain salt particles of all sizes, the sampling scoop must move at uniform rate across the entire *width* of the stream. Samples will generally be inaccurate if the scoop moves through the stream from front to rear.

2. The sampling interval should be uniform. And it is better to take small samples frequently than a few large samples.

3. The sampling scoop should have a relatively long rectangular opening, permitting a knife-like cut across the stream. The use of pails or shovels to sample the stream may produce an inaccurate sample.

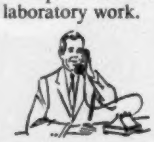
4. Sampling should take place on a regular stream flow. When taken from an intermittent flow, samples may not be representative. Also, sampling should be carried on throughout the entire unloading period.

Moisture content. Samples should not be taken from bulk rock salt which has recently been exposed to rainfall or excessive humidity. Under these conditions, the proportion of insolubles will increase due to the leaching out of a certain amount of salt. Resulting analysis will then show a higher degree of impurities and a lower sodium chloride content than is normally present.

Finally, it must be remembered that no matter where the salt is sampled—the larger the sample taken, the more representative it will be for final analysis. In fact, many industries require a gross sample of at least 100 lb. from one carload of salt. This sample is then reduced to about 5 lb. for laboratory work.

Sampling Tube Is the Simplest Method

Most sizes of rock salt can be sampled from stockpile, bins, trucks, or railroad cars by means of a simple sampling tube approximately 1¼" in diameter and about 6 ft. long. Five to eight insertions of this tube into the salt will furnish a sample of about 10 lb. Some of the best tubes for sampling rock salt are those sold for testing grain. They have about 12 openings and a special auger point.



TECHNICAL SERVICE WITH YOUR SALT

Through skilled and experienced "Salt Specialists," International can help you get greater efficiency and economy from the salt you use. International produces both Sterling Evaporated and Sterling Rock Salt in all grades for industry. And we also make automatic dissolvers in metal or plastic for both types of salt. So we have no reason to recommend one type of salt over another; we simply recommend the type and size of salt most perfectly suited to your needs.

If you'd like the assistance of an International "Salt Specialist" on any problem concerning salt or brine—or further information on salt sampling and analysis—just contact your nearest International sales office.

International Salt Co., Scranton, Pa.

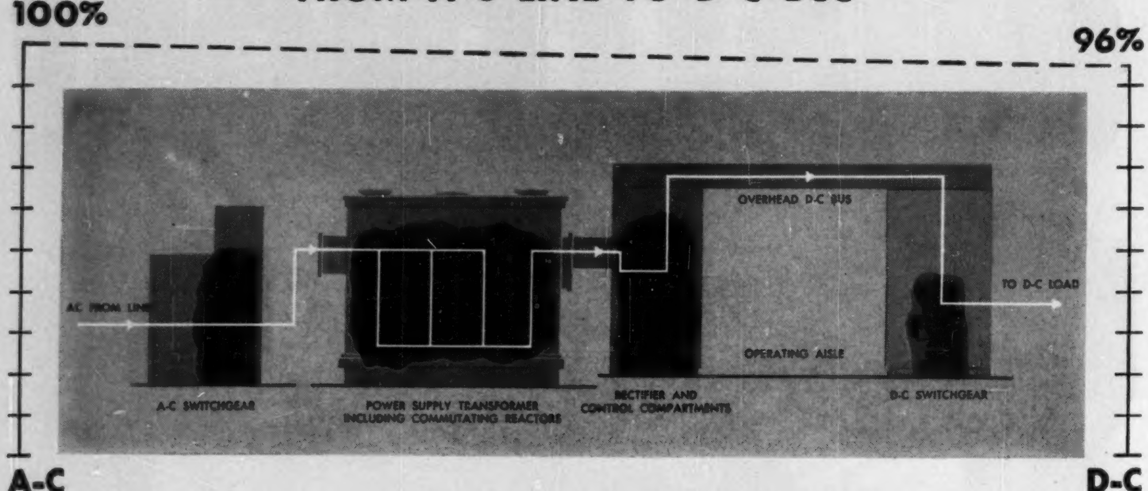
Sales Offices: Atlanta, Ga.; Chicago, Ill.; New Orleans, La.; Baltimore, Md.; Boston, Mass.; Detroit, Mich.; St. Louis, Mo.; Newark, N.J.; Buffalo, N.Y.; New York, N.Y.; Cincinnati, O.; Cleveland, O.; Philadelphia, Pa.; Pittsburgh, Pa.; and Richmond, Va.

FOR INDUSTRY, FARM, AND THE HOME—

STERLING SALT

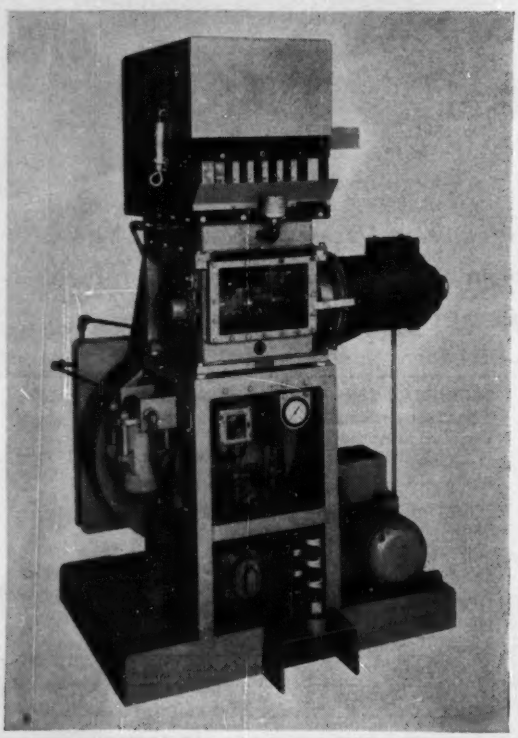
PRODUCT OF INTERNATIONAL SALT CO., INC.

FROM A-C LINE TO D-C BUS



Here's what you get. This drawing shows the essential parts of an I-T-E Mechanical Rectifier. Simple, compact equipment—easy to install, inexpensive to maintain.

POWER COST SAVINGS UP TO THOUSANDS OF DOLLARS A YEAR



The contact mechanism. This is the heart of the I-T-E Mechanical Rectifier. Synchronous motor drives silver contacts. Switching is done during interval when current is held at zero by reactors.

I-T-E Mechanical Rectifier operates at efficiencies of 96%—and higher!

The more d-c electricity you use in your manufacturing processes, the more you can save in the cost of your power if you have an I-T-E Mechanical Rectifier.

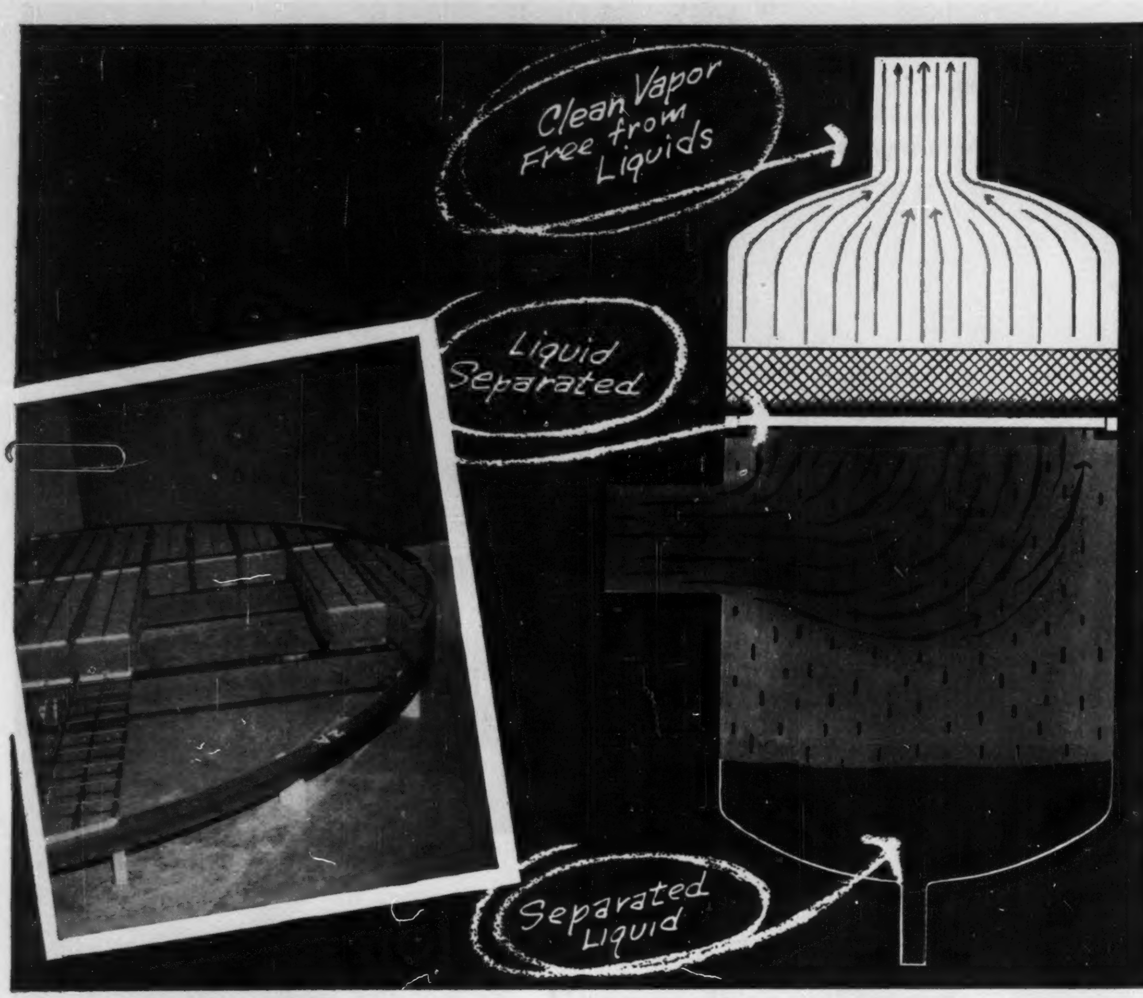
In case after case, I-T-E Mechanical Rectifiers have turned in efficiency performances of 96% and higher. Power losses are inherently lower. Contacts are pure solid silver—the best conductor known. Besides saving power, an I-T-E Mechanical Rectifier also saves you space, installation cost, and maintenance cost.

An I-T-E Mechanical Rectifier saves enough in power to fully pay the amortization costs on the equipment.

I-T-E Mechanical Rectifiers are available in single units—6000 through 12,000 amp and 24,000 amp from 50 to 250 volts d-c; 6000 amp and 12,000 amp from 250 to 400 volts d-c. For information, write I-T-E Circuit Breaker Company, Transformer and Rectifier Division, 19th & Hamilton Sts., Philadelphia 30, Pa.

I-T-E

I-T-E CIRCUIT BREAKER COMPANY • Transformer and Rectifier Division


Clean Vapor Free from Liquids
Liquid Separated
Separated Liquid

Buyers of Any Process Equipment Reap Benefits from M. W. Kellogg's

COMMITTEE WORK

ANOTHER PLUS IN KELLOGG'S

BUILT-IN ENGINEER

As a leader in the design and fabrication of petroleum and petrochemical process equipment, The M. W. Kellogg Company assumes many extra curricular responsibilities which eventually benefit not only its customers but the process industries in general. One of these responsibilities is Kellogg's participation in technical committees of professional societies and associations, particularly at subcommittee working levels.

At present, M. W. Kellogg's engineers, metallurgists and others give a considerable part of their time to over seventy such activities . . . ranging from boiler and pressure piping codes to welding practices and radiographic testing techniques. Many of today's accepted design concepts were introduced to the engineering profession by Kellogg committee men.

The M. W. Kellogg Company is privileged to contribute increasingly to the important work of technical and engineering societies, associations, and related groups. The practical application of the knowledge imparted and gained is another plus which goes into Kellogg's "built-in engineer" approach to process equipment design and fabrication. A typical example is a paper prepared by M. W. Kellogg engineers, "Collection and Correlation of High Temperature Hydrogen Sulfide Corrosion Data," and presented at a recent meeting of the National Association of Corrosion Engineers. *Write for your copy.*

Fabricated Products Division

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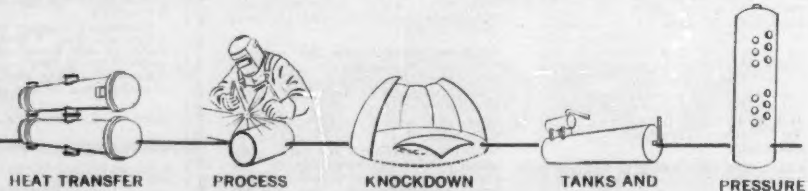
M KELLOGG W



BLASTED TO A FINISH

Wheelabrator's Liquamatte wet blasting machine imparts a clean finish—to close tolerances—in seconds. Abrasive slurry blasted by compressed air produces a uniform, non-directional surface on the work.

To change or dispose of abrasive slurries, Wheelabrator turned to Penberthy.

WHEELABRATOR REPORTS: "Penberthy Ejector is a simple, trouble-free device with long service life."

● Simplifying operations and saving time and money, Penberthy engineered products are gaining increasing attention in a diverse number of applications. Perhaps you can use them to advantage. In Wheelabrator's words:

"Our selection was made after considering Penberthy's skill in engineering and excellent service."

There's no obligation, of course, in getting complete facts on standard or custom designed Penberthy products. Available in a wide choice of materials.

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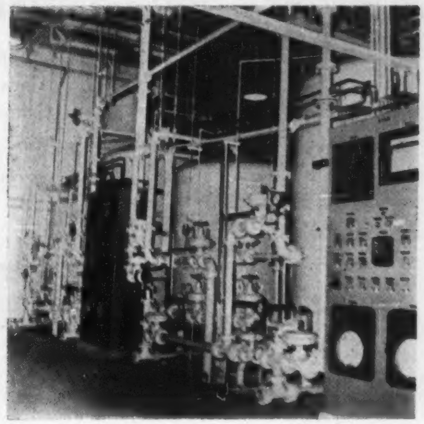
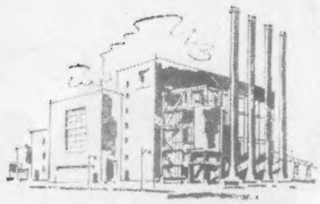
- CYCLING JET PUMPS
- ELECTRIC SUMP PUMPS
- LIQUID LEVEL GAGES
- GAGE VALVES

First in water conditioning

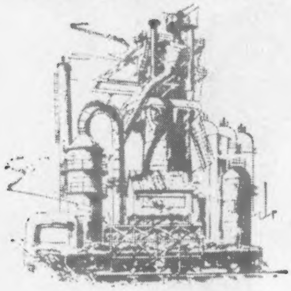
Installation below is a large paper mill. It provides an effluent with silica content below 0.02 ppm and total dissolved solids below 1.0 ppm. Total capacity 100,000 lbs/hr. for 1200 psi boiler.

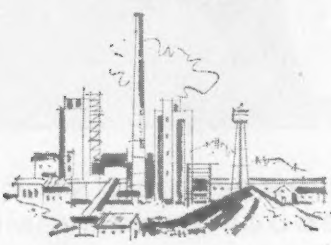




Cochrane DEMINERALIZERS

for efficient silica and solids reduction





Many of America's outstanding high-pressure steam generating plants are protected by Cochrane Demineralizers. The quality of demineralized water is superlative and Cochrane's progress in solving the many problems associated with demineralization is attested to by some of the largest installations in the world.

Cochrane's untiring staff of chemists, engineers and research men assure you of the answer to your water conditioning problem and continued satisfactory operation of your Cochrane installation.

Why not investigate the impressive list of Cochrane 2-bed, 3-bed, 4-bed and mixed bed Cochrane Demineralizer installations? For the answer to your water conditioning problems consult Cochrane's complete service first. Ask for Bulletin 5800.

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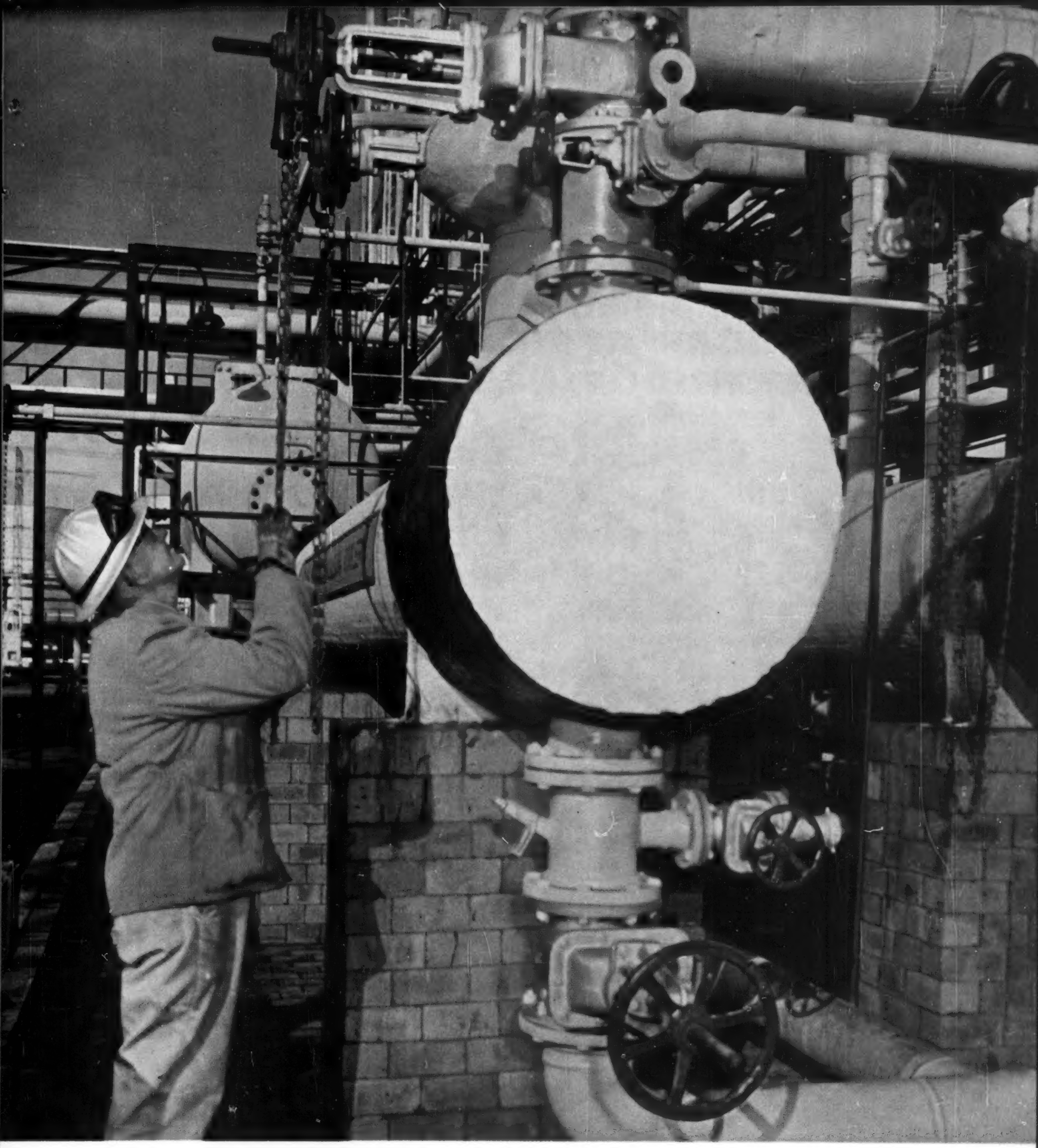
Ad No. 4.04



Closing the gate on hard-to-hold hydrocarbons

At Esso Standard Oil's Bayway Refinery light hydrocarbons are used extensively at a wide range of temperatures and pressures.

Light hydrocarbons are hard to "hold," but the self-adjusting wedge-design on Aloyco gate valves insures tight shut-off. Corrosion-resistant Aloyco valves — like the red-wheeled, chain-operated gate valve above — are used throughout many process units.

You'll see many more of them on key jobs at leading petroleum, processing and chemical plants throughout the country. What about your corrosives-handling problems? Write Alloy Steel Products Company, Inc., 1301 West Elizabeth Avenue, Linden, New Jersey.

6.2

Longer Lasting
ALOYCO
VALVES
1ST IN CORROSIVE SERVICE

Subsidiary of Walworth Company

CHEMICAL HAZARDS?

RESPIRATORY PROTECTION

Get the protection you need from these AMERICAN OPTICAL CHEMICAL CARTRIDGE RESPIRATORS

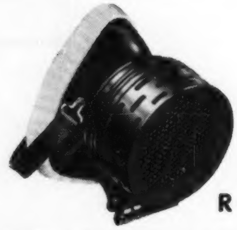
For Organic Vapors

R-5051
BM 2304

R-2031

For Acid Gases

R-5052



R-2032

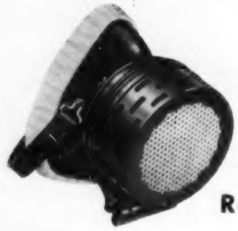
For Combined Organic Vapors and Acid Gases

R-5053

R-2033

For Ammonia

R-5054



R-2034

Your nearest AO Safety Products Representative can supply you. Write for literature.

American Optical
SAFETY PRODUCTS DIVISION

Note: Help prevent costly industrial eye accidents — look for the AO trademark on lenses and frames of safety glasses you buy.

SOUTHBRIDGE, MASSACHUSETTS • BRANCHES IN PRINCIPAL CITIES

ALLIS-CHALMERS High Pressure Barrel-Type COMPRESSORS

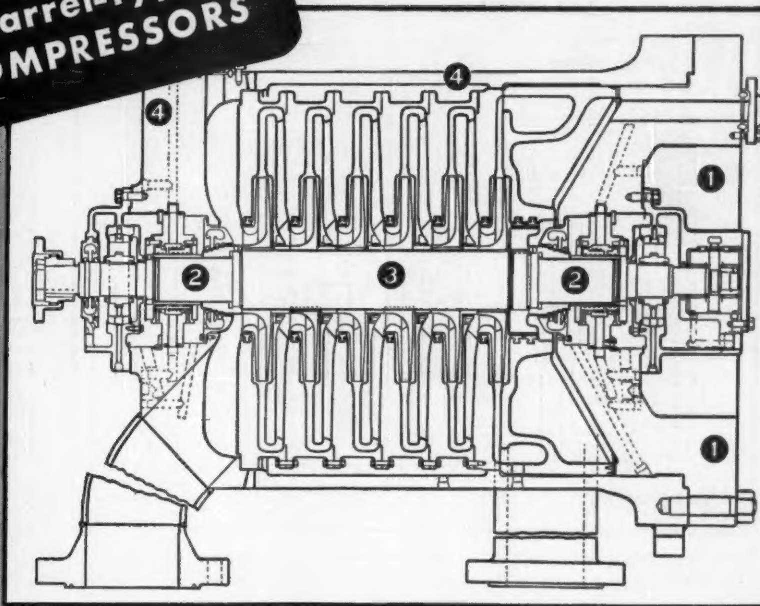
Features:

1
Simple to Maintain — Only one head bolted on. Spiral-wound metallic head gasket can be installed without cement or grease—quickly removed and reused if needed.

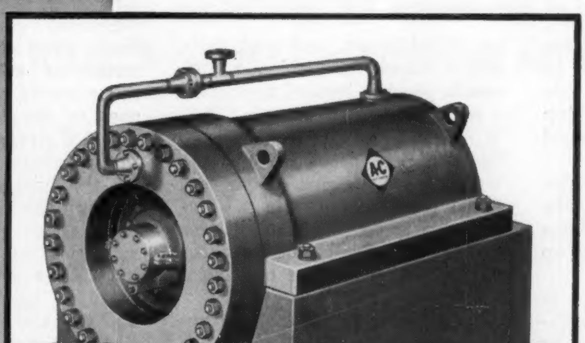
2
Shaft Sealing — Double bushing seals with separate high pressure seal oil system. Inward seal leakage minimized.

3
Rugged Rotor—For years of high speed operation. Impellers shrunk and keyed to shaft. Rugged riveted impellers with rivets milled integrally from blade edge.

4
Extra Strong — Vertically split forged steel casing — safe at high pressures.



Here's Unit Chosen for Reforming Process



This compressor is typical of Allis-Chalmers high pressure barrel units for "upgrading" processes.

Above are a few of the features that make it easy for maintenance men to keep equipment on stream around the calendar. Details of this design are yours for the asking. Call your nearby A-C office or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wis.

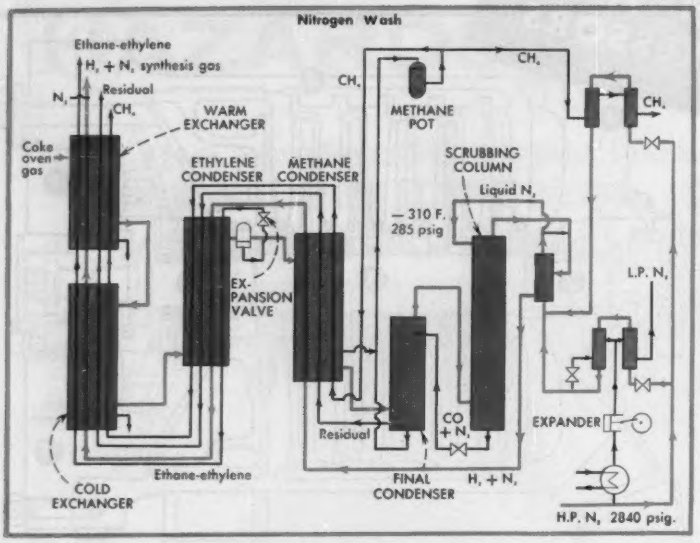
A-4967

A-C ALLIS-CHALMERS

ALLIS-CHALMERS

Pictured Flowsheet

EDITED BY R. B. NORDEN



Low-temperature separation process gives . . .

New Hydrogen Source for NH_3

Advancing low-temperature technology makes possible this first U.S. plant designed around coke-oven gas.

Low temperature process technology, long incubating in air separation units in this country, seems to be breaking out of its shell into the world of chemical processing.

An example of this trend can be found at Ketona Chemical's new 45,000 tons/yr. anhydrous ammonia plant just starting up at Birmingham, Ala.*

Operating the first plant in this country designed exclusively around coke-oven gas as a hydrogen source, Ketona removes impurities by low temperature condensation and liquid nitrogen scrubbing; produces nitrogen and oxygen in an air separation unit and combines H_2 and N_2 in a Claude ammonia converter.

▶Why This New Source?—Coke-oven gas is cheap, readily available at steel centers such as Birmingham, and cost estimates favor COG if the ammonia plant is located near such a center. However, the gas (55% H_2) is a complex mixture of light hydrocarbons with some sulfur and oxygen compounds. Until Ketona, ammonia producers preferred easier-to-process hydrogen sources such as natural gas, hydroformer hydrogen, Bunker C oil.

But advancing hydrogen-from-coke-oven-gas technology—much of it adapted from European plants—coupled with competition from natural gas as a heating fuel now permits process engineers to add coke-oven gas to the list of raw materials used in this country for ammonia production (see CE, Nov. 1955, p. 114). At the same time, the "impurities" recovered (methane, ethane-ethylene, benzene) and the O_2 available, could be used advantageously as chemical building blocks.

▶Low Temperature Processing—At Ketona low-temperature technology is concentrated in the Air Liquide condensation and nitrogen wash unit.

Coke-oven gas, previously purified of nitrogen oxide, hydrogen sulfide, CO_2 and benzene, is processed here. The gas at this point contains 57% H_2 and about 29% CH_4, at a pressure of 285 psig.

It first goes to either of two switch warm exchangers, where it's cooled by product streams (see cut at left). Additional cooling takes place in a cold exchanger (copper tubes) where ethane and heavier hydrocarbons condense.

In an ethylene condenser, the gas is further cooled to extract all the ethylene and ethane in liquid form. This ethylene-ethane is expanded to atmospheric pressure and vaporized in the previous exchangers. Here also, acetylene is scrubbed out with condensing ethylene.

The gas is then cooled in a methane condenser by countercurrent exchange with outflowing hydrogen-nitrogen, methane and residual streams.

Then it flows into the final condenser, where it's cooled and condensed by the residual $CO+N_2$ liquid from the liquid nitrogen scrubbing column. Here methane comes out as a liquid and goes to the methane pot. The residual stream returns through the previous exchangers. Part of the methane also returns through the exchangers; the remainder is used as auxiliary refrigeration for nitrogen.

▶Nitrogen Scrubbing—Free of most of the original methane and CO, the gas now enters the liquid nitrogen scrubbing column, where a countercurrent stream of descending liquid nitrogen at —310 F. removes remaining methane and CO.

A hydrogen-nitrogen mixture leaves the top of the column, while the nitrogen liquid with impurities comes off the bottom. The N_2+H_2 gas provides cooling for the incoming coke-oven gas.

▶Refrigeration Cycle—Cooling to operate the unit comes from an auxiliary nitrogen cycle tak-

* Ketona is jointly owned by Hercules Powder Co. and Alabama By-Products Corp. Plant was engineered by The Fluor Corp.

ing compressed nitrogen at 2,840 psig. from the air separation plant.

Nitrogen is first cooled partly by heat exchange with the methane fraction, and partly by heat exchange with nitrogen recycled from the high pressure N_2 stream. Part of the nitrogen is also cooled in an ammonia cooler and expanded in an expansion engine to provide additional cooling as compensation for radiation and warm-end heat exchanger losses.

Cooled high pressure nitrogen is expanded and partially liquefied. The liquid fraction is subcooled by heat exchange with the outgoing H_2+N_2 mixture before entering the wash column at —310 F and 285 psig.

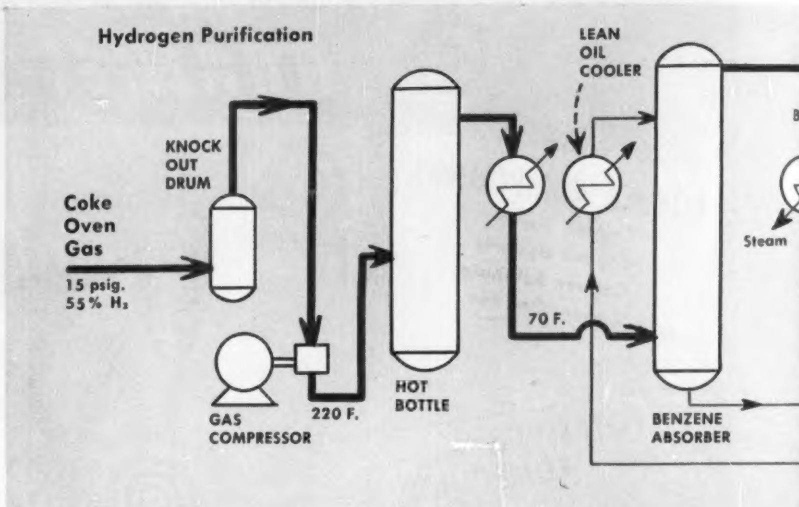
Final ammonia synthesis gas (75% H_2, 25% N_2) is made up by adding the proper amount of pure nitrogen.

► **Preliminary Purification**—Of course some preliminary treatment is necessary before the coke-oven gas is sent to the low-temperature wash unit. First raw coke-oven gas (after electrostatic and soda ash treatments) is compressed to 300 psig. and 220 F. It then goes to a "hot bottle" where high molecular weight contaminants polymerize into gummy tars and condense on the tower walls.

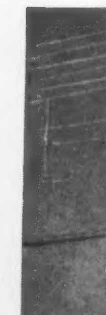
The gas is scrubbed with a light petroleum oil to remove aromatics, then with a 3% ammonia solution for CO_2 and sulfur. This is followed by a cold-water wash and a caustic solution scrub to get rid of the last traces of CO_2. The gas goes to the nitrogen scrubbing unit, then to ammonia synthesis.

► **Ammonia Synthesis Loop**—Synthesis gas compressed to around 9,000 psig. is sent through an oil filter before entering the Claude converter inlet. Here the fresh stream of H_2+N_2 joins with a recycle stream of unconverted hydrogen and nitrogen.

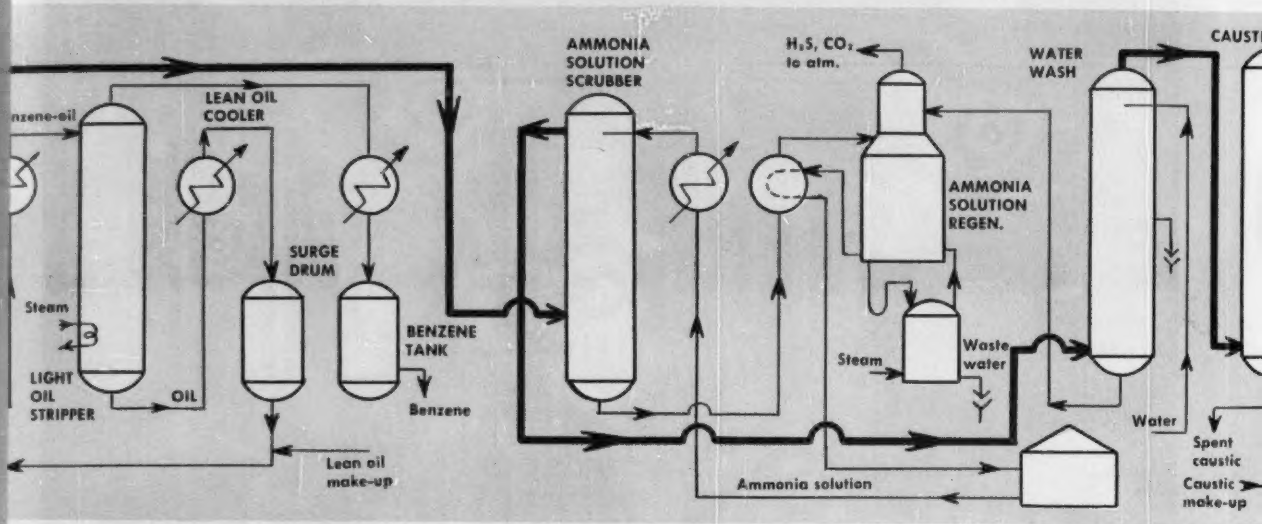
Inside the converter, the feed stream is heated by exchange with product gases, then passes through a bed of promoted iron oxide, where N_2 combines with H_2, forming ammonia. Effluent gases are condensed. Product is separated from unconverted gases, which are recycled.



1 **PURIFICATION towers remove gums, benzene, CO_2 and H_2S from coke-oven gas (300 psig.). Gas leaves with 57% (volume) H_2.**

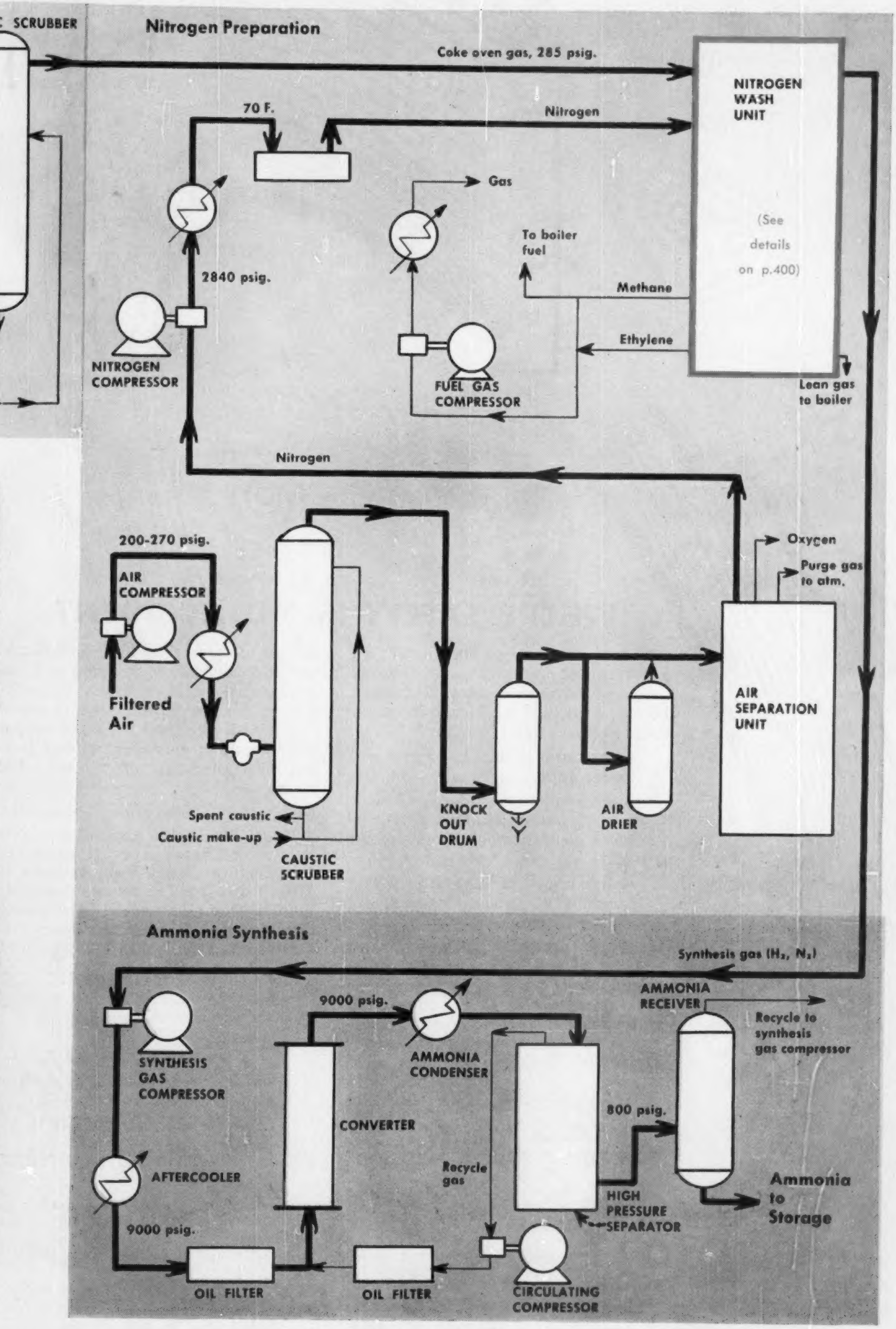


2 **LOW**
gas;



TEMPERATURE scrubbing unit yields ammonia synthesis
operates around −310 F. and 285 psig.

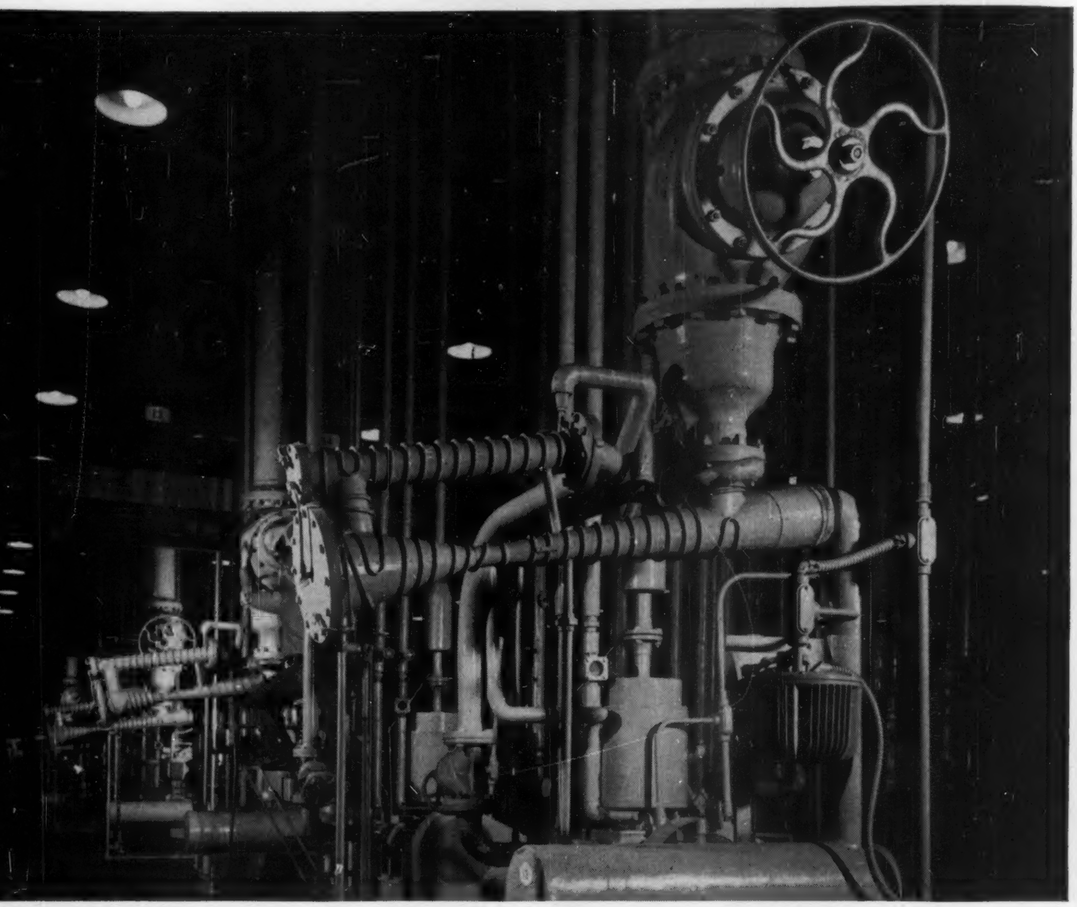
3 AIR SEPARATION takes place in a tonnage unit capable of turn-
ing out 3.78 million cfd. of nitrogen and 33 tons/day of oxygen



USTIC SCRUBBER
Nitrogen Preparation
Coke oven gas, 285 psig.
NITROGEN
WASH
UNIT
(See
details
on p.400)
70 F.
Nitrogen
Gas
To boiler
fuel
2840 psig.
Methane
Ethylene
NITROGEN
COMPRESSOR
FUEL GAS
COMPRESSOR
Lean gas
to boiler
Nitrogen
200-270 psig.
AIR
COMPRESSOR
Filtered
Air
Oxygen
Purge gas
to atm.
AIR
SEPARATION
UNIT
Spent caustic
Caustic make-up
CAUSTIC
SCRUBBER
KNOCK
OUT
DRUM
AIR
DRIER
Ammonia Synthesis
Synthesis gas (H_2, N_2)
AMMONIA
RECEIVER
Recycle to
synthesis
gas compressor
9000 psig.
SYNTHESIS
GAS
COMPRESSOR
AMMONIA
CONDENSER
CONVERTER
800 psig.
Recycle
gas
AFTERCOOLER
HIGH
PRESSURE
SEPARATOR
Ammonia
to
Storage
9000 psig.
OIL FILTER
OIL FILTER
CIRCULATING
COMPRESSOR

urn-
gen.

FLEXITALLIC
FLEXITALLIC



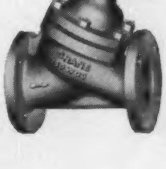
ese Crane valves holding 25 microns absolute pressure after 2 years on vacuum service

Case History—Valves fre-
ly are the most critical points
vacuum system. But that's
e case with this large South-
ht metals refiner.
s plant reports no trouble or
se over a 2-year period in
aining a vacuum of less than
crons absolute for its distilla-
rocess.
tight-holding valves installed
2 years ago on the lines from
m pumps shown above are
No. 1611 diaphragm pattern.
12-in. packless iron body
are used about once daily.

They've allowed no in-leakage at the seat, bonnet-joint, or through the diaphragm. No maintenance whatever has been given the valves since installed. They operate easily and look good for such service indefinitely.

This high efficiency performance is mainly due to Crane separate disc and diaphragm design. The diaphragm used as a bonnet seal only is not subject to destructive crushing. Conventional type disc and body seat provide a metal-to-Neoprene seating that's ideal for vacuum and hard-to-hold fluids.

Moderately priced, Crane diaphragm valves deserve your consideration for many ordinary services, as well as sludges, slurries and corrosive fluids. They are made in a wide variety of body and trim materials, in ½ to 12 in. sizes.



Ask your local Crane Representative about them, or write to address below for literature.

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Names in the News

EDITED BY M. A. GIBBONS

Charles R. Nelson: Man of the Month

Shell Development's pioneering process engineer is tagged this year's outstanding San Francisco Bay Area chemical engineer.

Out of sight is not always out of mind. Though he was in Holland on a short assignment while the award was being made, Charlie Nelson was his colleagues' unanimous choice for the title of 1956 outstanding chemical engineer in the San Francisco Bay Area.

Nelson's selection, by the AIChE's Northern California Section, is the second in a series highlighting annual Engineers' Week activities in the Bay Area (Chemical Engineering, April '55, p. 327). Last year, the emphasis was on young (under 40) engineers—with major attention focused on their contributions to the engineering profession.

This year, there was no age limit; and major attention was directed to the engineers' contributions to professional and community life as well. Nelson ranks high on both scores.

▶ Pioneer Process Engineer—Nelson is head of the process engineering department at Shell Development, where he has been employed since 1941. Somewhat like the company for which he works, Nelson got into the petrochemicals field early (in the mid-'30's) and took on process engineering when it too was a relatively new concept.

The two sections in Nelson's department—oil and chemical processing—are engaged primarily in the evaluation and design of oil refining and petrochemical processes. The department derives much of its personality and direction from its head, who long ago conceived of the process engineer as a breed apart from either chemists or chemical engineers.

Nelson looks at it this way. The process engineering department is the hub of the company's wheel of progress: it helps program research efforts, evaluates research results in view of company production facilities and policies, and adopts engineering development techniques to process design.

Primarily through his efforts, about 50% of the personnel in the department are Ph.D.'s—not for any design talents they might have but simply to help them to do a better job of understanding and working with research people.

▶ Vital Man on the Road—As the various Shell companies tended toward a higher percentage of Ph.D.'s on their research and engineering staffs, and as the supply of such personnel became more and more pinched, Nelson and other department heads saw the need to set up a joint Ph.D. recruiting program for the entire Shell organization. As a result, Nelson plows his way twice a year to MIT, Yale, Princeton, Delaware and Michigan. As a matter of fact, his recent trip to Holland was cut short because he had to return for his regular spring recruiting trip.

But one shortened trip could never disappoint Nelson to any great extent: Every time he turns around he finds himself overseas again—or on the way. In making good use of his interest in petrochemicals and process engineering, Shell Development sent him to England for six months in 1949, to Scotland for three months in 1951, and to Holland for two weeks, early this year, to assist with petrochemical plant installations.

Difficulty in adjusting to new locations is a problem that Nelson doesn't have to face. It has become too run-of-the-mill for him. He earned his B.S. in chemicial engineering, in 1930, at Carnegie Institute of Technology in what is today considered the East (despite the reference in the school's ancient alma mater to a "western"—i.e. Pittsburgh, Pa.—location). A few years later, he ended up in the Midwest, working for his M.S. and Ph.D. at the University of Michigan. And, just before settling in the West with Shell Development, he was employed by the General Chemical Division of Allied Chemical & Dye Corporation.

Nelson's frequent trips, particularly the European jaunts, sit rather sorely with his wife,

Molly (whom he married in 1940). Molly claims that in the first 10 years of their marriage Charlie was away at least one-third of the time. But things have improved recently. And, starting this June, the Nelson family, ensemble, will be one of three from Shell Development exchanged annually for a year with Shell researchers in Holland.

▶ **Professional Activities**—Nelson has been a member of the American Institute of Chemical Engineers since 1937. He was a charter member and first chairman of the Northern California Section (1944-45).

Not a member in name only, he's been mighty active too. As a member of the Institute's program committee (1943-47) and as vice-chairman (1945-46), he made the initial survey of the feasibility of holding national meetings on the West Coast. His conclusion was favorable, and somehow he became both program chairman and general chairman for the first West Coast national meeting of the Institute held in San Francisco in 1946. However, "Combining the program and general chairmanship in one man was a mistake neither seen before nor repeated since," he says, with a wry smile.

More recently, Nelson was a national director of the Institute (1951-53) and has been on the Education and Accrediting Committee since 1953.

▶ **Community Interests**—Just as strongly as he believes in process engineering as an engineering entity, Nelson believes even more strongly that engineers of all kinds should become interested in community affairs, particularly in local democratic processes.

His stand: "Engineers should apply their engineering know-how to community affairs; they should pitch in even if it means missing a professional meeting now and then." His observation: "Most engineers feel that doing extracurricular work for their engineering organizations is OK, but that community affairs are better left for the other guy."

Practicing what he preaches, Nelson is director and past

chairman of the Diablo Highway Improvement Federation (a citizens' advisory committee on highways in California's Contra Costa County). As such, he makes an annual trip to Sacramento to lobby before the State Highway Commission for increased appropriations for his local area.

He's also chairman of the Glorietta Improvement Assn., one of the citizens' ruling bodies in the unincorporated community of Orinda—where he resides with Molly and their three children (David, 13; Kip, 11; and Joy, 6).

What's more, he's chairman of the board of trustees of the Orinda Community Church—where he also managed to entice a couple of other engineers into making their community activities debut.

▶ **Any Time Left?**—In spite of his travels, professional work, and community activities, Nelson does have a home life too.

His hobbies are classical music (in years gone by he played a mean reed instrument), photography and, most recently but most avidly, trout fishing.

He was actually induced to take up fishing by his boys when they reported that other fathers took their kids on fishing treks. And the Nelson boys really relish those trips—every aspect of them. They go all the way: follow through on every detail. The boys even tie the flies; but their father is no purist. "I'll try anything in chemical engineering that will do the job, and in fishing I'll use anything that will catch a fish."

Actually, the major Nelson family activity is hiking and camping. Here, even Joy tags along carrying her small pack. With all of her father's professional and community interests, sometimes, she finds, that this is the only chance she has to be with him.

William G. Dedert is the new manager of the Swenson Pulp & Paper Division, Whiting Corp., Harvey, Ill.

H. G. Miller will be transferred from Dow Chemical's Texas Div. in Freeport, to the firm's

Midland, Mich., headquarters as manager of distribution development.

Jacob E. Jansen, with B. F. Goodrich Co. since 1938, has been named director of organic chemicals research in the company's research center, Brecksville, Ohio.

Philip M. Dinkins

Philip M. Dinkins was elected a member of the board of directors of General Aniline & Film Corp. Since, he first joined the firm in June 1955, Dinkins has served as vice president-operations for the Dyestuff & Chemical Division.

Long active in the chemical industry, Dinkins was president and director of the Jefferson Chemical Co., Inc., from 1946 to 1955, after having served since 1944 as vice president and general manager. Before that time he had been associated with American Cyanamid and its predecessors, since 1923. He was also a director of the latter firm.

Dinkins is a chemical engineering graduate of Massachusetts Institute of Technology.

George White, former executive vice president and director of the Vitro Corp. of America, has been named general manager of General Electric's atomic power equipment department. He replaces **Vice Admiral Willard A. Kitts 3rd,** USN (ret.) who is now manager of a new planning study for the department.

David N. McClanahan has been promoted to vice president in charge of process and chemical engineering for the Wyatt C. Hedrick Engineer-

ing Corp., Houston, Tex. **Edwin D. Redding** will take charge of project and design engineering.

Harry N. Huntzicker has been appointed executive vice president of American-Marietta Co. Huntzicker has been associated with United States Gypsum Co. for the past 20 years—most recently as vice president in charge of research and development.

Thomas P. McGuinness has been selected by the Barrett Division, Allied Chemical & Dye Corp., as supervisor of engineering, chemical products. His last completed assignment, in his former capacity as project engineer, was the construction of a synthetic phenol project in Philadelphia.

Thomas Clapper has been appointed associate director of research for American Potash & Chemical Corp., to head research facilities at the firm's Henderson, Nev., plant.

F. R. Ward, former technical assistant to the manager of the large ship reactor project, at Westinghouse Electric's Atomic Power Division, is now special assistant to the management of the Babcock & Wilcox Atomic Energy Division, in New York.

Harrison C. Givens, Jr., former manager of the manufacturing department, textile division, Celanese Corp. of America, has been named vice president-operations of Celanese International.

L. A. Johnson has been selected director of the new development laboratory of Chicago Vitrous Corp., Cicero, Ill., manufacturer of porcelain enamel processed glass ingredients.

Robert L. Clark is the new executive secretary of the National Committee for the Development of Scientists and Engineers. Clark comes to the Foundation from the Office of Defense Mobilization

where he served as consultant on the executive reserve since May 1955.

Charles F. Oldershaw, research supervisor in charge of chemical engineering for the Dow Chemical Co., at Pittsburg, Calif., has been appointed lecturer in chemical engineering at the University of California.

Bruce L. Calder, with 16 years experience in the chemical and engineering field, has joined the Flintkote Co. Previously, he had been affiliated with Toms River-Cincinnati Chemical Corp.

Oliver W. Weinkauff, an associate director of research for Monsanto Chemical, in St. Louis, has been appointed director of technology—a newly created position, in the organic chemicals division. **Harry W. Faust** will serve as Weinkauff's assistant.

F. Cushing Smith, who joined Standard Oil Co. (Ind.) in 1943 as a chemical engineer, has been promoted to the position of assistant to the president. Smith had been assistant superintendent of the Whiting refinery.

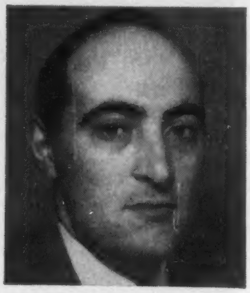
H. Von Bergen was elected president of the American Crystal Sugar Co. at a meeting of the directors in Denver. Since April 1955, he has served as executive vice president.

Edward J. Grabowski, assistant to the area manager for production at the AEC Dana plant near Newport, Ind., was transferred to the Washington AEC office of the Isotope Separation Branch, division of Production.

A. J. Valley has been appointed manager of the silvichemical division of Alaska Pine & Cellulose Ltd., Vancouver, B. C. His former experience was with the Koppers Co.

Richard O. Roblin, Jr. and **Robert P. Parker** were named assistant general managers of American Cyanamid's pig-

ments and research divisions. Roblin was co-discoverer of sulfadiazine; Parker is the former director of research at the Pearl River laboratories.



Robert F. Benenati

The only speaker from the United States to take part in a symposium to plan Switzerland's policy on the industrial use of atomic energy was Robert F. Benenati—member of the faculty of the department of chemical engineering at Polytechnic Institute of Brooklyn.

The symposium was held at Neuchatel on April 5, 6, and 7, under the auspices of the Society of Swiss Engineers and Architects.

During the war, Benenati was a nuclear reactor designer and engineering consultant. He headed the operating department of the Kellex Corp.—which designed and built the gas and diffusion plant for separating uranium isotopes at Oak Ridge.

J. H. Snyder, formerly mill manager for St. Regis Co., has joined the Nitrogen Division. Allied Chemical & Dye Corp. Snyder will be a sales development representative in promoting the use of Nitrogen Division's products in the paper industry, particularly ammonium bisulfite pulping.

Richard J. Bellet, research chemist, has joined the resins and plastics group of the research and development department of Hooker Electrochemical Co., Niagara Falls, N. Y.

Horace W. Boynton and **W. Mayo Smith, Jr.,** have been appointed assistant directors of research for Escambia Bay

Chemical Corp. Boynton will take charge of engineering and of fertilizer research; Smith will manage polymerization and plastics research and development operations.

Eger Vaughan Murphree

New special assistant for guided missiles, for the Secretary of Defense, is Eger Vaughan Murphree.

For the past twenty years, Murphree has been associated with Standard Oil (N. J.) research activities. For nearly ten years, he has been president of the Esso Research & Engineering Co. Under his guidance, the latter firm turned up a new process for using atomic radiation to produce more economical petroleum products.

Murphree had his early training in the fields of mathematics and chemistry. From 1922 to 1924, while working as a staff assistant and research associate in the Laboratory of Applied Science at MIT, he developed his interests in the industrial applications of chemical engineering.

His first association with the Esso organization dates back to 1930 when he joined Standard Oil of La. Some years later, he was transferred to New York as manager of development and research for Standard Oil Development (Esso Research predecessor).

Loren Miller, formerly with DuPont, has joined Fluor Corp., Ltd., as a research chemical engineer; **Donat Brice,** of Food Machinery & Chemical Corp., will join the firm in the same capacity; and **Robert Oliver,** previously with Union Oil, is a new senior research engineer.

B. W. Thomas has been promoted to senior research specialist in the technical and research divisions of Humble Oil & Refining Co., Baytown, Tex. **E. M. Amir** and **B. H. Johnson** have been advanced to senior research chemists.

Harry G. Drickamer, professor of chemical engineering at the University of Illinois and an authority on research at high pressures, has been presented with the $3,000 Ipatieff prize in chemistry for 1956, by the American Chemical Society.

Elmer F. Bell has been named assistant to H. E. Gessler, manager of industrial relations for Kaiser Aluminum & Chemical Corp. Before joining Kaiser, in 1951, Bell served with the Koppers Co.

Wilbur E. Kelley has been elected president of the Walter Kidde Nuclear Laboratories, Inc. Kelley has been associated with the atomic energy program since the early days of the wartime Manhattan District Project. For six years, he managed the New York Operations Office of the USAEC. Since 1953, he has been vice president in charge of engineering for Catalytic Construction Co., Philadelphia.

Perry R. Bish has been named to the newly created position as chemical engineer in the general engineering department of Allegheny Ludlum Steel Corp. He'll deal with problems arising from the use of water, acids, caustics and other chemical substances used in making the firm's products.

Willard F. Libby, of the USAEC, has received the 1956 $1,000 American Chemical Society Award for Nuclear Applications in Chemistry. Dr. Libby invented the "atomic time clock" method of measuring geological age as well as the screen-wall Geiger counter.

George E. Kimball, chemical physicist and pioneer in op-

erations research, will join the staff of Arthur D. Little, Inc., Cambridge, Mass., in July, as science advisor. A member of the Columbia University faculty for the past 20 years, Dr. Kimball has also served as consultant for ADL since 1950.

Henry L. Young

Chemical Engineer Henry L. Young has rejoined the textile colors division of Interchemical Corp., Hawthorne, N. J., as assistant to Division President William J. Rothemich.

Young first came to Interchemical in 1938. The following year, he became associated with Aridye Corp. (now the textile colors division).

Before his association with Interchemical, Young was market research director and assistant business manager of *Chemical Engineering* magazine. He was also co-author of the chapter on instrumentation in the first edition of Perry's "Chemical Engineers' Handbook" published by the McGraw-Hill Book Co.

Wesley C. L. Hemeon, engineering director of the Industrial Hygiene Foundation and Senior Fellow of the Mellon Institute, will resign his present post to become director of a new firm—Hemeon Associates—to conduct general consultation services on all aspects of air pollution.

L. W. Boerner, formerly chief engineer of National Foam System, Inc., has been named to a newly created position: vice president in charge of engineering. A native of Philadelphia and a graduate of Drexel Institute, Boerner has been with the firm since 1930.

Will W. White

Veteran of more than 25 years in the aviation fuel and lubricants field, Will W. White has been elected a vice president of Esso Research and Engineering Co.

White will function as a consultant and advisor, analyzing developments affecting petroleum products used in aircraft. The new position was created in recognition of the rapid growth of air transportation and the need to anticipate the various scientific problems which arise from such swift advances.

After graduation from the U. S. Military Academy in 1923, White earned an engineering degree at MIT. He joined what is now Esso Standard Oil Co., in 1930, but returned to active military duty in 1942 as a part of the newly formed Petroleum Administration for War in Washington in the Aviation Supply Dept.

George Rathmann is the new polymer section leader of the central research department, at Minnesota Mining & Mfg. Co. Rathmann joined 3M in 1951 as a chemist in the polymer section and, last year, became group supervisor.

Ray Ewald has been named technical services superintendent for Mobay Chemical Co.'s plant in New Martinsville, W. Va. Ewald replaces **Charles Koch** who has transferred to Mobay's development department to assist in the commercial development of urethane foams and surface coatings.

Proctor Thomson, of Cincinnati, noted for his work in

quality control as well as for pioneering in the application of statistical methods to chemical engineering problems, is the recipient of a University of Missouri Honor Award for Distinguished Service in Engineering.

E. Keith McMahon

The new director of development for the chemical, paint and metallurgical department of Merritt-Chapman & Scott Corp. is Dr. E. Keith McMahon.

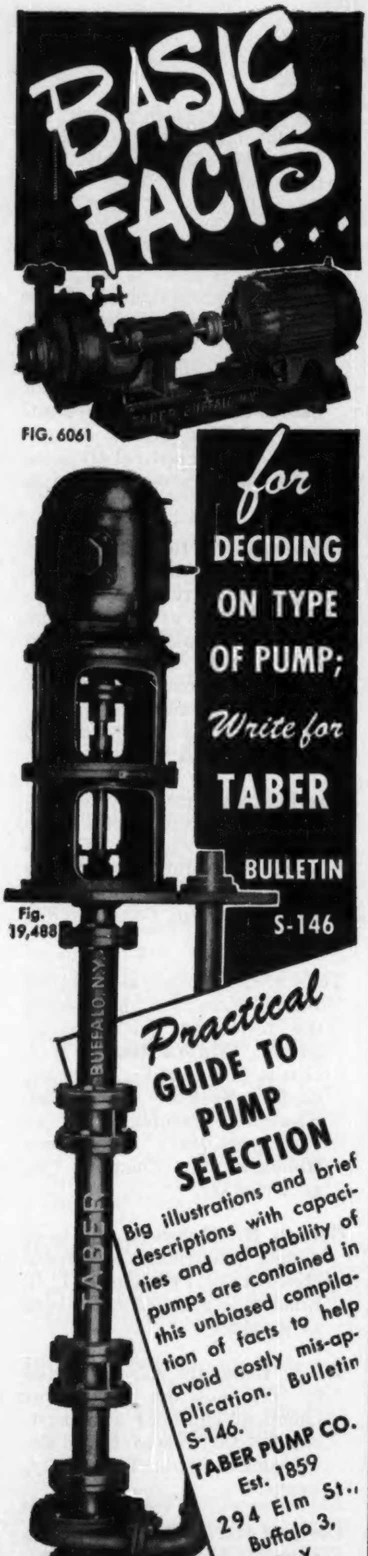
In his new post, McMahon will see to the growth and expansion of Devoe & Reynolds, Co., Inc., and Tennessee Products & Chemical Corp.—which comprise the department.

After graduation from Georgia Institute of Technology, in 1942, with a chemical engineering degree, McMahon joined Armstrong Cork Co. as a research engineer. Later, he accepted an appointment to the research staff of Columbia University where he earned his MS and Ph.D. degrees also in chemical engineering.

He joined the research staff of Tennessee Products & Chemical in 1949, where he became supervisor of its chemical engineering section. For the past two years, he has served as that firm's manager of technical sales development.

R. C. Vroom, a member of the board of directors of Peabody Engineering Corp., has been named vice president of the firm. Vroom, a graduate of Stevens Institute of Technology, has been with the firm for 33 years.

Van Zandt Williams, a vice president of the Perkin-Elmer Corp., has been named gen-



eral manager of the company's newly formed Instrument Div. Dr. Williams joined the firm in 1948 as director of instrument development.

Leslie E. Grosz has joined Parke, Davis & Co. as research assistant for products development. **John A. Panontin** has joined the chemical research department as an assistant research chemist.

L. K. Seely has been named manager of the gypsum board plant, Newark, Calif., of Pabco Products, Inc.; **R. K. Comann** will manage a similar plant in Florence, Colo.

Philip C. White, manager of the research and development department of American Oil Co., Texas City, Tex., has been appointed manager of research for Standard Oil Co. (Ind.) Dr. White replaces **J. H. Forrester** who will become president, at the end of this year, of a new chemical company to be formed by the consolidation of three chemical subsidiaries of Standard Oil.

Charles E. Kaddy has been appointed manager of construction for Singmaster & Breyer, Inc. He'll be responsible for the planning, scheduling and management of construction of all plants and facilities.

J. A. Gustin, formerly assistant manager and mill superintendent of the Gouverneur Talc Co. has opened his own office: J. A. Gustin & Associates, consulting engineers and technologists, with headquarters in Martinsville, Va.

Gabriel Appleman has been appointed asistant director of engineering at Foster D. Snell, Inc. Prior to 1952, Appleman worked 3 years as assistant to the director of research and development at Fertilizer & Chemicals Ltd.

Donato J. Bracco has been named manager of the chemistry laboratory of Sylvania Electric Products Inc. Before joining Sylvania, in 1947,

NAMES . . .

Bracco had been with the New York office of the USAEC, and the titanium division of National Lead.

Jan Oostermeyer, former head of Shell Chemical Co., has been named president of the Association for Applied Solar Energy for the coming year.

John H. Wents, Jr., has been named assistant general manager of Tide Water Associated Oil Co.'s central division, with headquarters in Tulsa, Okla.

Christopher G. Boland has been appointed manager of the market research and development section of U. S. Industrial Chemicals' development department. Before joining USI, three years ago, he had been associated with Distillation Products Industries and W. R. Grace & Co.

Charles Lay, formerly vice president of Upstate Metal Casting Co., Norwich, N. Y., has been appointed molding equipment service manager of Shallway Corp., Connellsville, Pa.

Twin Cities Chemical & Allied Trades Assn., Inc., have made the following new appointments: **Clifford Barth,** Merchants Chemical Co., as president; **Norman Anderson,** Hawkins Chemical Co., as vice president; and **Bruce Heimark,** Dow Chemical Co., as secretary.

Gordon H. Chambers has been named chairman of Foote Mineral Co., Phildelphia. **L. G. Bliss** will succeed Chambers as president.

W. A. Bonawitz was promoted to the position of senior chemical engineer at American Oil Co., research and development dept., Texas City, Texas.

Gerhard Harold Beyer, who was appointed professor of chemical engineering at the University of Missouri, earlier this year, has been named chairman of the department.

Raymond W. Hess

Recipient of the 1956 Jacob F. Schoellkopf medal of the western New York section of the American Chemical Society is Raymond W. Hess, coordinator of Pollution Research for operating improvements for the National Aniline Division.

The award was presented "for outstanding contributions to the solution of the chemical, social and economic problems associated with the control of pollution . . ."

After graduation from the University of Illinois where he received his Ph.D. in chemistry (1916), he was employed by Sherwin Williams Co. to do research on dyestuffs. A few years later, he joined National Aniline in Buffalo and, since that time, has been involved in various research, development and production activities in the fields of dyestuffs and pollution research.

Wilbert F. Huntley, has been selected as director of blast furnace operations on the staff of the vice president-production at Jones & Laughlin Steel Corp.

David G. Hill, former vice president of glass mfg., Pittsburgh Plate Glass Co., has been elected president.

Joseph E. Ross is now leader of American Viscose's tire yarn section, research and development section, at Marcus Hook, Pa.

Howard J. Daly has been elected to the new post of vice president in charge of crude abrasive plants for the Norton Co., Worcester, Mass.

A. J. Seidule and **I. R. Zelade** have been named assistant

superintendents in Dow Chemical's Texas division organic production department.

James E. Domke has been named technical assistant, organic chemicals group at Wyandotte Chemicals Corp.'s Michigan Alkali Division.

EAVESDROPPING

"The need for scientists should not be a function of the temperature of the Soviet's fever . . . ."
George G. Manov*

"Much has been said concerning the urgency of meeting the Soviet challenge to our technical leadership and matching their output of scientists and engineers instead of falling further and further behind. This is an urgent problem, without doubt and would justify stockpiling scientists for this purpose alone.

"But there is a broader perspective that we must not lose sight of —that it should not be the Soviets who would be significantly responsible for whatever educational policies this country might establish in the near future.

"The larger problem is this: it should be clearly recognized that even if the tensions of the cold war were to cease and 'if peace were to break out' today, this country would need even more scientists and engineers than under a war-time economy. The need for scientists should not be a function of the temperature of the Soviet's fever."

*George G. Manov, technical assistant to Commissioner Willard F. Libby, USAEC, delivered at Phillips Academy, Andover, Mass., March 6, 1956.

OBITUARIES

Carl Pletscher, retired first vice president and general manager of Baker Perkins, Inc., died April 4, at the age of 76. The firm credits most of the successful development of its Saginaw, Mich., plant to his resourcefulness.

Colonel Evan Ewan Kimble, associated with Owens Illinois Co. and the Scientific apparatus Makers Assn., died March 16, at the age of 87. Kimble's fight, after World War 1, against duty free im-

portation of laboratory glassware, resulted in legislation which aided the industry's domestic development.

Alfred A. Halden

Executive vice president and director of National Starch Products, Inc., Alfred Halden, died March 22, just ten weeks after a heart attack. He was 61 years old.

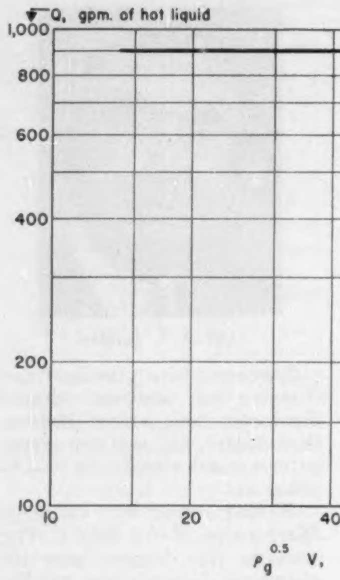
Halden served with Chemical Warfare in World War I after earning his degree from the Columbia College Chemical Engineering School in 1917. Soon after, he joined National Starch where in quick succession he became manager of the Plainfield, N. J., plant; a director, in 1932; secretary of the firm, in 1938; and a few years later, vice president in charge of manufacturing.

Over the years, he also served the industry in various capacities as trustee of the Corn Industries Research Foundation, director of the Adhesives Association of America and a member of the American Chemical Society, Sigma Xi, and Chemist Club organizations.

Frederick H. Leonhardt, 83, dean of the American essential oil industry, and chairman of the board of Fritzsche Bros., Inc., died on April 10, at his home in Douglaston, N. Y. He had been associated with the firm for nearly 60 years.

Ollison Craig, vice president of Riley Stoker Corp., died April 3, in Florida, where he was vacationing. The 68 year old engineer had been instrumental in the development of the firm's combustion equipment.

Letters:



Still More on Tray Design

Sir:

I read with interest the article, "Save Money on Bubble-Cap Columns," by Walsh and Lafyatis in your April issue (pp. 193-6).

May I point out one thing overlooked by the authors? Vapor-handling capacity is limited by tower diameter. Allowable vapor velocity is usually expressed

$$u = K\,[(\rho_l - \rho_g)/\rho_g]^{0.5}$$

where K is a constant depending on tray spacing and static seal. For the tower cited in the article, $K = 0.25$ according to the graph on p. 430 of Robinson and Gilliland's "Elements of Fractional Distillation" (4th ed.).

In many cases the simpler form,

$$u = K(\rho_l/\rho_g)^{0.5}$$

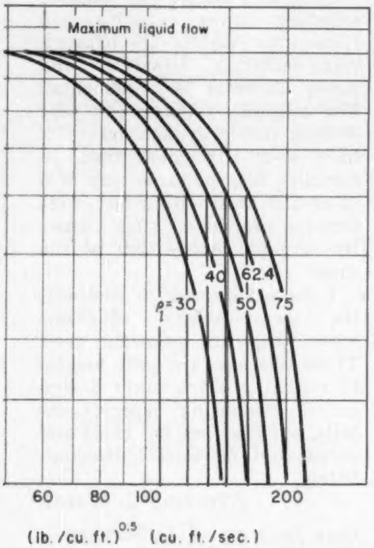
is a fair approximation. This can be rewritten in terms of the abscissa of the authors' master chart:

$$\rho_g^{0.5} V = K\,\rho_l^{0.5} A_t$$

where A_t is the cross-sectional area of the tower. For the

Pro & Con

C. H. CHILTON



sample illustration used by the authors,

$$\rho_g^{0.5} V = 19.6\ \rho_l^{0.5}$$

For the master chart the following additional limits should be drawn:

ρ_l	$\rho_g^{0.5}\ V$
30	107
40	123
50	138
62.4	154
75	169

R. L. SHANNON
Koppers Co.
Pittsburgh, Pa.

▶ *The above graph shows the vapor-handling limits suggested by Reader Shannon. However, Author Walsh questions the validity of these limits, as brought out in his reply below.*—ED.

Con: Tower Diameter Limit

Sir:

Relationships of the type suggested by Mr. Shannon are modifications of the entrainment relationship originally developed by Brown and Souders. They depend for success upon uniformity of tray designs. Although such equations can be used for a first approximation of tower capacity when the tray

PRO & CON . . .

design is conventional, tower capacity as calculated by these equations may be as much as 40% from actual capacity.

Consideration of the factors affecting tower capacity will show that relationship between vapor-handling capacity and tower diameter is coincidental. For example, suppose you take a 10-ft.-dia. tray and insert it in a 10-ft.-I.D. shell; then, in contrast, use the same tray in a 12-ft.-I.D. shell with a 1-ft.-wide annular supporting ring. Capacity of both towers will be the same.

I do not intend to discredit the vapor-velocity equations when they are properly used. These relations are quite helpful in roughing out a tower design before evaluating capacity details, but they are not exact and should not be used indiscriminately.

THOMAS J. WALSH

Case Institute of Technology
Cleveland, Ohio.

▶ *Earlier reader comment on the Walsh-Lafyatis article appeared in this department last month (pp. 307-8).*—ED.

Wrong-Way Corrigan

Sir:

I have read with great interest your articles regarding general considerations in reactor design (CE Refresher, Sept., Oct. and Nov. 1955). They are certainly nice contributions to this field.

However, I would like to draw your attention to p. 213 of the October issue, wherein Messrs. Corrigan and Young discussed the effect of pressure on first-order reactions. The equation

$$k_p = k_c/RT$$

does not follow from what they stated therein, and consequently the equation

$$p_A = p_{A0}e^{-bt/RT}$$

where

$$b = se^{-E/RT}$$

does not seem to be correct. Here's why:

Start with the basic rate equation,

$$-dC_A/dt = k_cC_A$$

But

$$C_A = n_A/V = p_A/RT$$

Therefore,

$$-d(n_A/V)/dt = k_c(p_A/RT)$$
$$= -d(p_A/RT)/dt$$

and

$$-d(p_A/RT)/dt = (k_c/RT)p_A$$

Now, how can

$$-dp_A/dt = k_p p_A$$

as the authors state, when

$$k_p = k_c/RT$$

I would like to suggest the following derivation for this case:

Picking up after the third step above,

$$-dp_A/dt = RT(k_c/RT)p_A$$
$$= RTk_p p_A$$

The substitution here is based on

$$k_p = k_c/RT$$

Or if

$$-dp_A/dt = k_p p_A$$

then

$$k_p = k_c$$

Therefore,

$$p_A = p_{A_0}e^{-bt}$$

where

$$b = k_p = k_c$$
$$= se^{-E/RT}$$

GUNVANT C. SUTARIA
Syracuse, N. Y.

▶ *Dr. Corrigan clears up this error in his reply which follows.*—ED.

Pro: Correct Derivation

Sir:

Mr. Sutaria is absolutely correct. The derivation which we showed was incorrect because we brought the rate equation down to the form $-dp_A/dt$. With the rate defined as $-dp_A/dt = k_p p_A$, then the rate constants k_p and k_c would be equal, as shown in the corrected derivation.

It is only where the rate is defined as

$$-d(n_A/v)/dt = k_p p_A$$

that the RT factor would be used. This latter definition of rate is the one used by Hougen and Watson in their text on homogeneous kinetics, and by this definition the rate is equal to lb.-moles of reactant A converted per cu. ft. of reactor volume per hr. In order to integrate this form of the equation the partial pressure has to be converted to moles of A.

The form which we presented for rate,

$$-dp_A/dt = k_p p_A$$

apparently is not used as frequently as the other two forms of the equation. *(Continued)*

In the corrected derivation, k_p is equal to k_c only for the first order, as shown. The general case for integral order would be

$$k_c = k_p(RT)^{n-1}$$

I want to thank Mr. Sutaria for calling my attention to this error, and I will of course correct it if I revise these articles.

THOMAS E. CORRIGAN
Olin Mathieson Chemical Corp.
Brandenburg, Ky.

Con: Weight Lifting

Sir:

Until you are able to sell a *Chemical Engineering* subscription to all the boys in our office, I would appreciate one small change in the format of the cover page—a small rectangular box where I could write my name. The tail of a hot neutron on the March cover and the fractionating tower on the April cover are poor substitutes for just a little white space.

If the magazine puts on any more weight, we will have to prohibit our secretaries from lifting it, but it is too much to expect any corrective action on this score.

RUSSELL C. PHILLIPS
Stanford Research Institute
Menlo Park, Calif.

► *Our secretary improves her poise and posture by carrying copies of CE—instead of the traditional book—on her head.*—ED.

Pro: Complete Fileability

Sir:

I am interested in keeping the best and latest pertinent information on important engineering subjects in my personal files. In

your March issue several articles of permanent interest to me were published back to back, making separate filing impossible.

In order to provide complete fileability, I offer the following suggestions for your evaluation:

- Start all articles on the right-hand page. If the article length is other than an even number of pages, fill in the space to the next right-hand page with: Blank space (this was done in *Trans. AIChE*); memorials to great men, writers, editors, scientists, statesmen, etc.; jokes, anecdotes, etc.; pictures (aesthetic values only, no nomograms or flowsheets unless related to the article); specially selected innocuous advertising.
- Print pages of articles which are back to back on special paper which can be split into separate sheets as *National Geographic* did at one time.

HUGH SPENCER
B. F. Goodrich Chemical Co.
Cleveland, Ohio

Pro: Prandtl Number

Sir:

I have a few comments on "Estimating Thermal Conductivity of Gases," by Om P. Kharbanda (Sept. 1955, p. 214).

It seems to me that Mr. Kharbanda is starting off on rather a shaky basis when he uses the Sutherland-type equation for relating viscosity and thermal conductivity. From this basis he obtains constancy of μ/k at various temperatures. This deduction, combined with the generally accepted fact of constancy of $c_p\mu/k$ at various temperatures, leads to the absurdity of constant c_p with varying temperature.

I prefer to start from the Prandtl number, which is generally agreed to be independent of both temperature and pressure. This holds for permanent gases except near the critical region.

Having the Prandtl number (about 0.70 for gases cited), you can easily obtain the ratio μ/k, since all you need is the molar specific heat at the temperature in question. From then on I follow the same procedure as Mr. Kharbanda; to obtain k, I use a value of μ derived from the literature. (*Continued*)

PRO AND CON . . .

I feel that my procedure yields more exact values of k at high temperatures, since it is based on two sound propositions—constancy of the Prandtl number (within limits) and accurate specific heat data.

Furthermore, there is no need to have one value of k at low temperature.

Marc L. Aelion
Laborterapica S. A.
Sao Paulo, Brazil

► *Mr. Kharbanda defends his position in the following letter.*—Ed.

Pro: Sutherland Equation

Sir:

I'm surprised to learn that the basis of the Sutherland equation is "rather shaky."

The constant in this equation is a "measure of the strength of the mutual attraction of the molecules" (Chapman & Cowling, "The Mathematical Theory of Nonuniform Gases," 1933), and it may well be possible to calculate it on the basis of the molecular model of the individual gases. As to the applicability of this equation, both for viscosity and thermal conductivity, I relied on the information in McAdams as quoted in the article.

Regarding the method suggested by Mr. Aelion: The constancy of Prandtl number is indeed very well known, and this fact is often used for calculating the missing data.

However, the constancy of Prandtl number is purely fortuitous and, to the best of my knowledge, has no theoretical basis or explanation. Major limitation in use of Prandtl number is that all the data for c_p, μ and k must refer to the same temperature. In order to calculate k at any temperature, both c_p and μ at that temperature must be known. In the method suggested in my article, μ at that temperature and k at any low temperature are required.

O. P. Kharbanda
Simon-Carves Ltd.
Stockport, England

► *To help resolve this international difference of opinion, we have asked an impartial third party to help clear the air. He sides with Brazil.*—Ed.

It's Prandtl by 2 to 1

Sir:

The arguments of Messrs. Aelion and Kharbanda reflect individual viewpoints more than anything else. However, I attach some favor to Mr. Aelion's proposal.

As he observed, if both constant $c_p\mu/k$ and constant μ/k are assumed, then c_p must be independent of temperature; this is definitely not so. Therefore, one or the other of the assumptions must be wrong. On the basis of the following reasons, I choose the $c_p\mu/k$ approach as possessing greater generality and utility:

- The Sutherland constant is not as theoretically sound as Mr. Kharbanda supposes; it has merely been *interpreted* as a *measure* of mutual molecular attraction.
- Both experimental and calculated viscosity values are generally considered more accurate than the corresponding values of thermal conductivity.
- Specific heat data are far more available and accurate than even low-temperature thermal conductivity data, which Mr. Kharbanda's approach would require.
- Both Maxwell's and Eucken's theoretical treatments of gaseous thermal conductivity, each of which are well tested, correspond more closely to the assumption of constant $c_p\mu/k$ than to the assumption of constant μ/k.
- Mr. Kharbanda's method requires a viscosity value at the same temperature at which k is to be evaluated; Mr. Aelion's, a c_p value at the same temperature. And if μ is known at a given temperature, c_p will almost certainly be known with at least as great an accuracy at the same temperature, thus invalidating Mr. Kharbanda's objection to data requirements.

In practice, there appears to be little to choose between the two procedures for common gases, since the deviations from best experimental data are almost identical. But in a new application, I would, for the reasons cited, use the constant Prandtl number approach.

W. R. GAMBILL
Carbide & Carbon Chemicals Co.
S. Charleston, W. Va.

THIS MONTH'S

Technical

Timely Text From Britain

PLASTICS PROGRESS 1955. Philosophical Library, New York. 432 pages. $17.50.

Reviewed by A. L. Griff

This book contains the full texts of papers presented at the British Plastics Convention in June, 1955. Similar volumes were published after the 1951 and 1953 conventions.

The papers cover a wide variety of subjects related to the plastics industry — including patents; work study and productivity; reports of advances in polymer chemistry, fabrication techniques and new applications. And it is this diversity of subject matter which makes such a book valuable, especially to the man who works in a rather limited segment of the plastics industry—perhaps with one or two types of material or with one fabrication method. By reading such a collection, you can get not only factual information, but also a valuable insight into the problems and over-all achievements of many branches of the plastics field.

The British origin of the writings doesn't make their subject matter less timely to the American reader. On the contrary, the papers often discuss pertinent American developments and practices, capably treating many items just coming into their own in this country, e.g., glass-reinforced plastics in automobile construction, polyurethane foams, irradiated polyethylene and other polymers. In fact, the papers are a bit more interesting because of their British flavor, which often reflects England's closeness to France and Germany, and a correspondingly greater concern with developments in these countries.

This volume is easier to read than most technical literature. It's filled with numerous and informative charts and pictures, including many photographs and reproductions of slides. Further-

Bookshelf

EDITED BY R. K. GITLIN

more, the discussion following presentation of the papers at the convention have been recorded and are printed here along with the papers. Some of these discussions are rather spirited. And all serve to answer questions which the reader might well raise in the course of his reading.

Among the most interesting articles is "Patents and the Plastics Industry." Plastics are used here as examples in a clearly written description of British patent law, how it operates in actual practice and how it compares with patent laws and practices of many other countries, including ours. It's notably free of confusing legal language and therefore a lot more readable.

Another well presented article deals with blowing agents used in the manufacture of foamed rubber and plastics. It provides a thorough summary of what's required in a blowing agent, what agents are available in England and elsewhere and what they can and cannot do. Compounds and classes of compounds with potential application as foaming agents are also discussed.

The price ($17.50) of this volume will no doubt deter most individuals from buying a copy. But public and corporation libraries should definitely have it on their bookshelves. It should be of considerable interest and value to anyone at all concerned with the plastics industry.

Deserves Special Attention

PROCESS ENGINEERING ECONOMICS. By H. E. Schweyer. McGraw-Hill Book Co., New York. 409 pages. $7.50

Reviewed by J. B. Weaver

The approximate science of chemical engineering cost estimation has never before been related to the exact science of engineering economy. And it is

high time that this relationship was established, as it is in this book.

Techniques of equipment and plant investment estimation and product manufacturing cost estimation have been covered extensively in the literature (including the pages of this magazine). But it is a little surprising that until now no chemical engineer has taken a comprehensive look at techniques of profitability estimation and economic balance in processing calculations. A few authors like Happel and Jelen have incorporated some of the principles of engineering economy in single techniques they've advocated. Although excellent texts on engineering economy have been available (i.e., Grant and Thuesen), the examples and context are not slanted to the chemical process industries.

In his book, Professor Schweyer starts from fundamentals—capital and interest, time value of money—and leads the student (young or old) through equivalent ways of expressing the value of money at various interest rates. After a chapter on amortization and depreciation, he reviews literature on capital investment estimation for process plants. In contrast to Aries & Newton's recent text, Schweyer is careful to consider reliability of such estimates.

Balance sheets and sources of capital are covered before the end of this chapter, while the next chapter covers the related items of manufacturing costs, earnings, profits and returns, income statements, fixed and variable costs, breakeven charts and incremental costs.

The remaining seven chapters cover various phases of profitability estimation-economics of alternatives, replacement and economic balance in various unit operations, cyclic operations, yield and recovery, inventory and process operations, complete processes. Examples chosen from the chemical process industries make these concepts much more available to chemical engineers than they have ever been.

Schweyer's reliance on Grant is shown by his fifteen refer-

ences to Grant's text, "Principles of Engineering Economy." Grant, however, thought the 1954 tax law revisions were important enough to depreciation accounting to require a revised version of his text, "Depreciation." Schweyer dismisses all types of depreciation allowances except straight line with a single wave of a footnote p. 32). Nowhere is it recognized or exemplified that the new rapid depreciation methods show their real value in terms of engineer-economy, where the time value of the early return of this investment is recognized. This seems a major omission which later editions should rectify.

Confusion in terminology is nothing new in engineering economics, but it contributes here to an important weakness. The "capitalized" concept isn't defined as such, but is used early in the book (pp. 7, 13) in its usual sense—a dollar value expressing the present worth of a perpetual series of earnings or payments, at a given interest rate. Later, however, the term "capitalized" is used to refer to ratios of dollars described neither as perpetual nor present-value. On page 98, the ratio of profit to total investment (often called "return on original investment") is called the "capitalized earning rate," although the dollar figures, from income statement and balance sheet, are not perpetual. The ratio does express the interest rate which would convert a net profit, as a perpetual annual receipt, to a total investment, as a capitalized cost. However, such a ratio isn't intended to take account of the time value of money and therefore doesn't merit the "capitalized" tag.

Confusion seems to be compounded on page 164 where "capitalized earning rate" (or "return on original investment") is used to evaluate an actual sample case, compared with the "economic earning rate" or interest rate of return. The latter, Schweyer says, is accurate but "tedious". "Capitalized earning rate" gives the wrong answer, but since it is easier to calculate, the method is apparently considered acceptable. There's similar doubt that "capitalized pay-

BOOKSHELF . . .

out time" merits the adjective "capitalized," since the time value of money isn't taken into account.

The numbering of the various parts of a chapter may lead to some confusion. Starting with section 5-5, for instance, we find equations 5-2 to 5-4, figures 5-1 to 5-3, then examples 5-1 through 5-4 (including equations 5-5 through 5-9) and finally a long discussion apparently still part of section 5-5. Tables are also numbered in a separate series. The lack of any mark signifying the end of an example makes it particularly difficult to skim the principles of the book without taking time for the examples.

This volume's reference system is a handy one, completely in footnotes instead of a single book or chapter citation list. The most common disadvantages of such a system—hard-to-trace "ibid." and "op. cit."—aren't completely absent, but are used sparingly (only within chapters where a citation is used twice). This system made author-indexing potentially so easy that it's hard to see why the index covers only the first mention of an author's name. Question on bibliographic technique: Is it proper for Schweyer to quote Schweyer (pp. 62, 66) as if he were an independent expert?

The appendix contains a summary of some useful material-equipment, construction and operating costs, estimated lives for certain equipment and annually compounded interest tables. It also has a glossary of selected terms which is said to include "accounting and economic terms having a special significance as used in this text. The meaning of other terms employed less frequently may be found by using the index."

The implication here is that only the more frequently used terms have special meaning. But actually the glossary seems to cover frequently-used terms—some, but not all, having a special meaning. Some definitions don't make the main point of a special definition previously made in the text, i.e. "earning" as defined on p. 99. The "capitalized concept" might be defined here to advantage, as well

as "annual cost," "equivalence," "present worth," etc. Definition of "total investment" should include working capital, as it does on p. 65.

But all these are minor criticisms. The knowledge here should be a real asset to chemical engineers responsible for dollars. Reviewers often say a book "deserves space on every chemical engineer's shelf." If most shelves are like mine, too many of the books were put there to be read when regular work lets up a little. This one deserves more—study it and the devil with shelf space, regular work and all.

Briefly Noted

INVESTIGATION AND DEVELOPMENT OF HIGH-TEMPERATURE STRUCTURAL ADHESIVES. 128 *pages*, $3. *By H. N. Homeyer, Jr., et al. Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.* Evaluation of a number of commercially compounded, metal-to-metal structural adhesives. Among the materials evaluated (following shear strength tests at various temperatures): silicone resins, rubbers, copolymers. Also evaluated were various primers, fillers, methods of preparing metal surfaces for bonding.

INFLUENCE OF GRINDING FLUIDS UPON RESIDUAL STRESSES IN HARDENED STEEL. 7 *pages. By H. R. Letner. Mellon Institute, 4400 Fifth Ave., Pittsburgh 13, Pa.* Reprint of a paper published in January, 1956. Describes experiments in which air, two concentrations of rust inhibitor in water, six watermiscible oils and four straight grinding oils were used to investigate effect of grinding fluid on residual stresses in hardened steel by surface grinding.

DEINKING OF WASTE PAPER. TAPPI Monograph Series—No. 16. 187 *pages*. $5. *Technical Association of the Pulp and Paper Industry, 155 East 44th St., New York, N. Y.* Ten chapters, contributed by 18 authors, cover: Historical review and statistics, gathering and sorting of waste paper, mill testing of waste paper, sorting practices in waste paper use, theory of deinking, cooking and defibering operations, elimination of undesirable material from cooked

deinked stock, alkali and heat recovery, bleaching of deinked paper stock, characteristics and treatment of deinking wastes.

MECHANICAL CHART DRIVES. 3 *pages. Scientific Apparatus Makers Assn., 522 Fifth Ave., New York 36, N. Y.* Tentative standard RC 11-5-1955 produced by SAMA's Recorder-Controller section. Applies to spring-driven chart drives for recording industrial instruments using circular charts. Four-part standard includes specs for chart drive dimensions and performance requirements.

DUST EXPLOSIONS IN FACTORIES: THE PROTECTION OF PLANT BY HINGED EXPLOSION DOORS. 23 *pages. 25¢. By K. C. Brown and D. G. Wilde. Safety in Mines Research Establishment, Ministry of Fuel and Power, Portobello St., Sheffield 1, England.* Describes work on protection of plants against industrial explosion by use of pressure relief vents. Includes a section on experimental plants and methods (explosion door, methods of ignition, dust samples) and results.

PIPELINES TO THE FUTURE—A STUDY OF PLASTIC PIPE. 64 *pages. $1. Public Relations Dept., Monsanto Chemical Co., Sprinfield 2, Mass.* Analyzes and evaluates plastic pipe market. Heart of book is in detailed charts and tables comparing performance and cost of important plastic and metal pipe materials and list of advantages and limitations of major plastic types. Other highlights: prediction of future for plastic pipe industry; analysis of manufacturing and distribution costs of polyethylene, cellulose acetate butyrate, styrene copolymers, rigid polyvinyl chloride, reinforced polyesters.

REFUSE COLLECTION AND DISPOSAL FOR THE SMALL COMMUNITY. 39 *pages, Public Health Service, U. S. Dept. of Health, Education and Welfare, Washington, D. C.* A joint study and report of the Public Health Service and American Public Works Assn., Chicago. Discusses storage, collection and disposal of refuse—methods and financing. Charts supply information such as: number of compactor trucks needed per given population, monthly trench capacity required. Schematics show various types of refuse dumps and methods of sanitary landfill.

AMERICAN STANDARD SCHEME FOR THE IDENTIFICATION OF PIPING SYSTEMS. 7 *pages.* $1. *Order Dept., American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y.* Covers identification of piping systems in industrial and power plants (doesn't include pipes buried in the ground or electrical conduits). Although prepared to specify identification of contents of piping systems primarily on the basis of stenciled legends, standard also provides for the use of color as a secondary means of identifying the type of material contained in the system.

PROCEEDINGS OF THE 19TH ANNUAL TIME AND MOTION STUDY AND MANAGEMENT CLINIC. 152 *pages.* $5. *Industrial Management Society, 35 East Wacker Drive, Chicago 1, Ill.* Complete transcripts of talks by top leaders of labor, management and government on various topics including time study, motion economy, methods, plant layout, production control, wage incentives maintenance and human relations. Text is illustrated with charts, forms, etc.

HIGH-TEMPERATURE REACTIONS OF URANIUM DIOXIDE WITH VARIOUS METAL OXIDES. 32 *pages.* 20¢. *U. S. Government Printing Office, Division of Public Documents, Washington 25, D. C.* Report of studies instituted in the National Bureau of Standards for the determination of the phase-equilibrium relations of binary systems containing UO_2 and various metal oxides. Review of unclassified literature is included.

MORE NEW BOOKS

CHEMICAL SAFETY SUPERVISION. By J. Guelich. Reinhold. $4.50

HIGH TEMPERATURE TECHNOLOGY. Edited by I. E. Campbell. Wiley. $15.

LEGAL PROBLEMS IN ENGINEERING. By M. Nord. Wiley. $7.50.

METALLURGICAL THERMOCHEMISTRY. By O. Kubaschewski and E. L. Evans. Wiley. $10.

SURVEYING INSTRUMENTS AND METHODS. 2nd ed. By P. Kissam. McGraw-Hill. $5.75.

THEORY OF COMBUSTION INSTABILITY IN LIQUID PROPELLANT ROCKET MOTORS. Agardograph 8. By L. Crocco and S. Cheng. Butterworths Scientific Publications. $5.25.

THIS MONTH'S

Firms in

New Locations

Gardner Laboratory has moved into a new building at 5521 Landy Lane, Bethesda, Md.

Air Reduction Co. has moved the general offices of its Colton Chemical Co. division to 1747 Chester Ave., Cleveland.

New Representatives

Cleaver-Brooks Co. has appointed R. F. MacDonald Co., San Francisco, as representative for the sale of its boiler equipment in northern California and western Nevada.

Foremost Food and Chemical Co., El Dorado Div., has appointed F. W. Kamin Co. its sales agent for northeastern Ohio.

Cambridge Wire Cloth Co., Cambridge, Md., has appointed the Green-Penny Co., Oakland, Calif., and Robert Abel Co., Brookline, Mass., as selective distributors for its line of Gripper woven wire slings.

Kemtek Corp., Newark, N. J., has established two additional distributorships for its line of extruded nylon rod: Buyers Service, Cleveland; Graef Engineering Co., Paramount, Calif.

New Companies

Hastings Plastics, Inc., Santa Monica, Calif., has been formed to manufacture and distribute compounded resins and related materials for industrial applications in the electronic, low pressure laminating and plastic tooling fields.

T. I. W. Western Ltd. has been formed by Toronto Iron Works Ltd. and Canadian Kellogg Co., Ltd., to provide increased fabricating serv-

the News

EDITED BY F. ARNE

ices to industry in western Canada.

Alco Oil & Chemical Corp. (Ohio) has been formed as a result of a merger of Alco Oil & Chemical Corp. of Philadelphia (latex chemicals) and Rainbow Production Corp. of Cleveland (crude oil).

American Petrofina has been formed with the Belgian petroleum group, Petrofina, and Canadian Petrofina each holding a $10-million interest.

Foiltone Products Inc., a wholly-owned subsidiary of National Research Corp., has been formed to take advantage commercially of National's achievements in continuous metal coating in a vacuum.

New Lines

Bennett Industries, Peotone, Ill., has begun mass production of steel drums in both standard type and hi-bake containers.

Ball Bros. Co. has acquired exclusive manufacturing and sales rights to an electronic weight and force indicating device developed for industrial uses and control of loads in air and surface transportation by Control Cells Corp., Boulder, Colo.

U. S. Hoffman Machinery Corp. has entered the atomic energy field through purchase of a majority interest in Anton Electronic Laboratories, Brooklyn producer of nucleonic and electronic equipment and components.

New Facilities

Diamond Alkali Co. is doubling capacity of perchlorethylene at Deer Park, Tex. The company has also approved plans

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for increasing production capacity by 42 percent (800,000 bbl./yr.) at its Standard portland cement plant in Painesville, Ohio.

Waverly Petroleum Products Co., Philadelphia, has started up a $250,000 plant near Meigs, Ga., to mine and process Fuller's Earth.

Diamond Match Co. will start operations next year of a $15-million integrated forest products plant at Red Bluff, Calif. It will process 85 million bd. ft. annually.

Victor Chemical Works plans a sizable expansion in both phosphorous and phosphate producing capacity. And central research facilities at Chicago Heights, Ill., will be increased 50%.

Courtaulds (Alabama) Inc. has started construction of a textile research and development laboratory and pilot plant at the company's plant site at Mobile, Ala.

West End Chemical Co., Oakland, Calif., is doubling its 50,000-ton/yr. sodium sulphate-salt cake facilities.

British Petroleum Co. plans to build one of the world's largest catalytic gas-making installations relying solely on oil as raw material. The 20-million-cu. ft./day plant will be completed in Kent, England, by the end of 1958.

Gladding-McBean Co., Seattle, has contracted with Washington Natural Gas Co. for over 1 million cu. ft./day of natural gas to fire its kilns and furnaces.

Longview Fibre Co., Longview, Wash., is building a furnace to produce steam and recover chemicals from liquor spent in processing 575 tons of pulp daily. One of the world's largest, the furnace will be completed by summer of 1957.

Foote Mineral Co. has acquired Electro Manganese Corp. of

Knoxville, Tenn., producer of the pure manganese metal used principally in alloying steel and other products.

Bakelite de Mexico, S. A., has started up a 2-million lb./yr., $160,000 phenol-formaldehyde resins plant in Monterrey.

Armour Research Foundation has established a research section to concentrate on metallurgical problems in the atomic energy field.

National Aniline Div., Allied Chemical & Dye Corp., has announced plans for erection of an addition to its research-engineering center located at its Buffalo, N. Y., plant. Space will be devoted to applications research on diisocyanates.

Davison Chemical Co. has started construction of a research and development laboratory near Baltimore.

Dow Chemical Co. has opened a $1.1-million laboratory for research in biochemistry in Midland, Mich.

New Jersey Zinc Co. has acquired American Cyanamid's plant at Gloucester City, N. J., to manufacture titanium dioxide pigments.

Arizona Chemical Co. has established a new process development laboratory at Panama City, Fla.

Nopco Chemical Co., Harrison, N. J., has acquired land in North Arlington, N. J., on which it will erect laboratories, offices, and production facilities.

General American Transportation Corp. plans a research and development laboratory in East Chicago, Ind., for its plastics division.

Imperial Chemical Industries at its Wilton plant in Cheshire, England, plans start-up of further plants for olefin production and butadiene extraction, a second

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para-xylene and terylene units and a plant for a range of copolymers used in making emulsion paints and shoe-soling products.

Harbison-Walker Refractories Co. plans to build a basic refractories plant at Hammond, Ind.

American Smelting & Refining Co. is considering building of a $4-million plant at Ruston, Wash., to derive sulfur dioxide from wastes created in the copper smelting process.

Commercial Solvents Corp. has established a southeastern district sales office in Atlanta, Ga., for its agricultural chemicals department.

Esso Research and Engineering has contracted with Battelle Memorial Institute to conduct experiments using a nuclear reactor nearing completion to perfect ways of using nuclear radiation in petroleum refining and in the production of petrochemicals.

M. W. Kellogg Co. has established a western regional office in San Francisco.

Metal & Thermit Corp. has acquired the Glenn Co., Oakland, Calif., makers of constant voltage power sources.

Phillips Petroleum Co. has acquired about 950 acres of land with frontage on the ship channel near Houston, Tex., which it will develop as sites for sale to others as plant locations. Plans for the sites anticipate the availability by pipeline of natural gas, ethylene, brine and other materials.

Stepan Chemical Co. has completed a 10-million lb./yr. sulfonated detergent bases plant in Joliet, Ill. Also completed: A 7-million lb./yr. ethylene oxide products plant that will turn out ethoxylated alkyl phenols and nitrogen-containing detergent bases; a

5-million lb./yr. alkyl phenol plant.

Dominion Tar & Chemical Co. plans to build a $5-million crude tar distillation plant at Hamilton, Ont.

Morton Salt Co. has completed a multi-million-dollar laboratory building in Woodstock, Ill., for its research and development department.

U. S. Industrial Chemicals Co. in Tuscola, Ill., has just put on stream an anhydrous alcohol unit said to be the world's largest.

Hooker Electrochemical is doubling capacity of its polyester resin manufacturing facilities.

British Oxygen Co. Ltd. has built a plant near Dundee, Scotland, to compress 500,000 cu. ft./wk. of oxygen. Installation includes a unit for production of 350,000 cu. ft./wk. of dissolved acetylene.

International Cement Corp. is building a $8-million cement plant near Vancouver, B. C.

U. S. Department of Agriculture has contracted to have the Naugatuck Chemical Div. of U.S. Rubber investigate the incorporation of tung oil and tung fatty acids in polyester resins to develop new high-strength resins for industrial use.

Gulf Oil Corp. will spend $35 million on new installations either begun or completed this year at its Philadelphia refinery. The new units include a 26,000 bbl./day catalytic reforming unit, a

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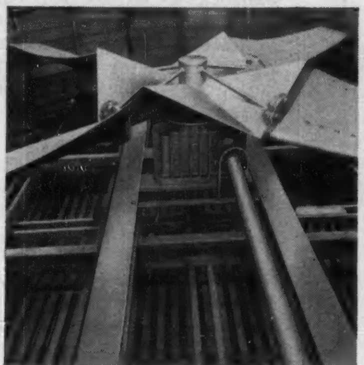

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FIRMS . . .

3,000 bbl./day alkylation unit, two Gulfining units with capacities of 20,000 bbl./day each. Also planned is a third ethylene plant at its Port Arthur, Tex., works, to cost $10-15 million.

California Oil Co. plans to spend $1 million on a 25% increase in platformer capacity of its 70,000 bbl./day refinery at Perth Amboy, N. J.

Atlantic Refining Co. has started on an $11.5-million expansion of its Philadelphia and Port Arthur, Tex., refineries to upgrade gasoline quality and increase anhydrous ammonia output.

Indiana Farm Bureau Cooperative Assn. will spend $1.25 million on a 3,000-bbl./day platformer and a 2,100-bbl./-day unifiner for its Mt. Vernon, Ind., refinery.

Esso Standard Oil Co. plans to spend about $40 million for improvement and extension to plant equipment at its Baton Rouge refinery.

Schering Corp. plans an accelerated program of plant expansion in excess of $2 million annually for the next several years.

African Pyrethrum Development, Inc. will build a pyrethrum-extraction plant in Nakuru, Kenya, Africa, with a capacity of 2,500-3,000 tons of flowers a year.

Borg-Warner Corp. plans to spend about $25 million on expansion this year. One project is the Marbon Chemical Div's $10-million chemical plant in Washington, W. Va.

Clark Oil & Refining Co., Milwaukee, is spending $1.75 million in 1956 to increase capacity and efficiency of its refining operations.

National Lead Co. will increase capacity of the die casting facilities of its Doehler-Jarvis Div. by 20 million lb. of aluminum and 15 million

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THE NEW SEALOL FLEXIBOX SEALECTOR ENABLES YOU TO DECIDE ON SEAL TYPE SIZE AND MATERIALS FOR YOUR SPECIFIC REQUIREMENTS. THE SEALECTOR COVERS 48 TYPICAL PRODUCTS BEING HANDLED IN THE PROCESS INDUSTRIES.

HERE'S HOW IT WORKS—

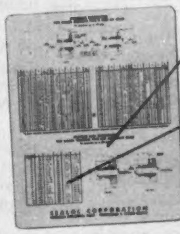
Typical Example — Butane @ 250 PSIG, 160°F — Shaft Size 1⅝"

1. FRONT
PROCEDURE — STEP I — *AUTOMATIC SELECTION OF SEAL TYPE AND MATERIAL — SET POINTER ON PRODUCT:*

TYPE —
RRCB FLEXIBOX
RR = BALANCED DESIGN
C = CIRCULATED PRODUCT
B = THROTTLE BUSHING

MATERIAL —
STATIONARY SEAL RING — CARBON
ROTARY SEAL RING — TYPE 347 STAINLESS STEEL
ROTARY SEAL RING FACE — STELLITE
SPRING — TYPE 18-8 STAINLESS STEEL
GLAND PLATE — STEEL, PLATED
O RINGS — BUNA BASE RUBBER

2. BACK
STEP II — *DETERMINE SEAL SIZE FROM SHAFT DIMENSION:*



TYPE = RRCB
SHAFT = 1.625"
MIN. STUFFING BOX BORE = 2.625"
MIN. BOX DEPTH = 2.625"
SEAL SIZE = 40

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SEALOL
THE BALANCED PRESSURE SEAL

expansion of its production and research facilities.

General Electric Co.'s X-Ray Dept. in Milwaukee has created separate marketing sections to give individual service to medical and industrial X-ray apparatus.

Brazil's Atomic Energy Commission has contracted with Babcock & Wilcox for construction and installation of a "swimming pool" atomic research reactor which will probably be located at the University of Sao Paulo.

Automatic Control Co., St. Paul, is building a plant addition which will more than double its floor space.

University of California's Los Alamos Scientific Laboratory has completed a new administration and laboratory building.

B. C. Cement Co., Ltd. will establish a $1.5-million distributing center on the Fraser River to serve the lower mainland of British Columbia.

Textron American, Inc., has acquired General Cement Mfg. Co., Rockford, Ill., which makes technical aids for servicing and research in the television and electronics field.

Texas Co. has started an expansion at its Port Arthur, Tex., refinery to boost steam generating capacity by about 32% and electric generator capacity by about 29%.

Arrowhead and Puritas Waters, Inc., has purchased McLaughlin Glass Co., Los Angeles. Plans are to expand plant capacity to manufacture large carboys.

Monsanto Chemical Co. has acquired an equity interest in Etino-Quimica, S. A., Barcelona, Spain, a manufacturer of polyvinyl chloride.

Texas Adams Oil Co. has purchased the United States

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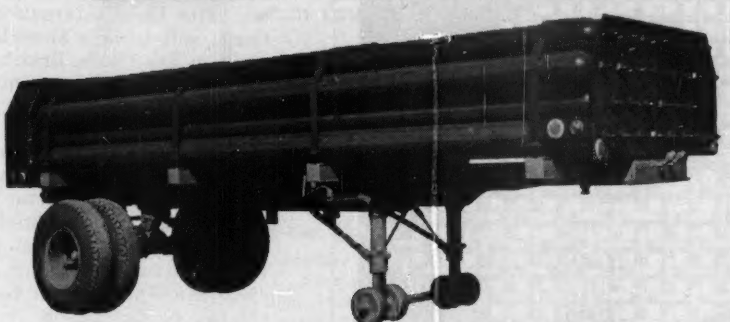

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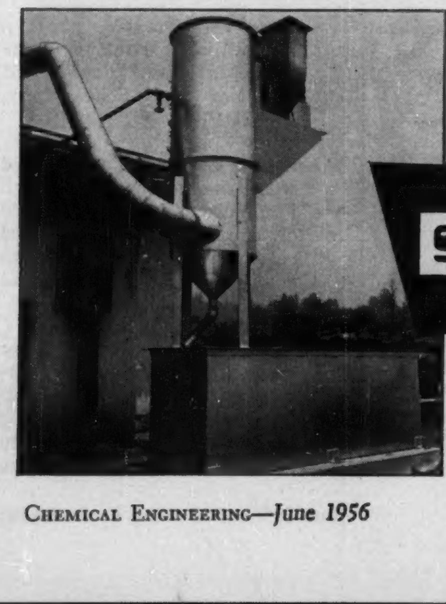
Be sure to get all the answers before you allocate any money for dust control equipment.

Your nearest Schneible engineer is at your service, or if you like, call the home office, collect.



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In the open position with piston fully retracted, there is no resistance to flow of materials drained from the tank.

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Designed for bolting to existing flanges. For special adaptations and for jacketed vessels, adaptor pads are available.

Full Specifications on Application

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FIRMS . . .

lb. of zinc. Expansion, to be completed this year, will take place at plants in Toledo, Pottstown, Pa., Grand Rapids, Mich., and Hamilton, Ont.

Minneapolis-Honeywell Regulator Co.'s Micro Switch division has opened a new plant near Independence, Iowa.

W. R. Grace & Co., in conjunction with Eriez International Corp., will build a $1-million plant in Sao Paulo, Brazil, to manufacture permanent magnet alloys.

Dow Chemical Co.'s Texas Div., Freeport, Tex., has new facilities for extensive research in agriculture. Studies involving as many as 160 farm animals and up to 4,000 chickens or other poultry can be carried on.

Nuclear Science and Engineering Corp. of Pittsburgh, Pa., is building a new and additional laboratory facility for its department of biology and medicine.

Clark Equipment Co.'s industrial truck division has started operation of a plant in Richmond, Calif.

Empire Steel Castings, Inc., Reading, Pa., has installed new $85,000 induction melting furnaces which will enable the foundry to increase its line of corrosion resistant steel casting.

General Electric Co. plans a $6.8-million expansion of its gas turbine department facilities in Schenectady, N. Y.

Union of Burma has contracted with the Armour Research Foundation to spend $200,000 on expansion of the applied research institute at Rangoon, and metallurgical and mineralogical research.

G. D. Searle & Co., Chicago medical research and pharmaceutical manufacturing organization, has acquired land in Cook County, Ill., to hold as a site for long-range

FIRMS . . .

Sulphur Co., owners of one of the country's largest surface sulfur deposits. They are in the area of Dunton, Colo.

Producing Properties, Inc., Dallas, has purchased 15 of Witco Chemical Co.'s oil and gas wells, which are located in Texas and New Mexico, for $1.75 million. Witco has sold all 25 of its wells.

Allied Chemical & Dye Corp. has opened a district sales office at St. Paul, Minn., for its nitrogen division.

Reliance Electric and Engineering Co. is building a $1.25-million office building in Euclid, Ohio.

Keokuk Electro-Metals Co. has increased the capacity of its Wenatchee, Wash., plant for the production of silicon metal by one third.

National Gypsum Co. has started development of a new asbestos mine and plant near Quebec which will be completed in 1958.

Bayer Works is setting up three new plants in Rio de Janeiro, Brazil: one will transform chromium ore into chromates; another will turn out insecticides; a third will produce dyes and varnishes.

Magic Chemical Co., Brockton, Mass., has acquired the Peerless Cement Co., manufacturer of industrial adhesives.

Badische Anilin and Soda Factories and the Friedrich Uhre, Ltd., both of West Germany, and the French Compagnie Industrielle de Traveau have jointly signed contracts with the Egyptian government to share in the construction of a 400,000 ton/yr. fertilizer plant near Assuan in Egypt.

Airmatic Valve, Inc., manufacturer of air controlled valves, has tripled its Cleveland facilities.

General Refractories Co. of Canada, Ltd. has started construction of a new plant at

FIRMS . . .

Smithville, Ont., to manufacture fire brick and refractory specialties.

Glidden Co., Cleveland, has announced an expansion of its Reading, Pa., paint making facilities which will add 100,000 gal./mo. capacity bringing it to 750,000 gal./mo. Cost will total about $750,000.

Commonwealth Oil Refining has started construction of facilities that will more than double capacity of its 23,000 bbl./day refinery near Ponce, Puerto Rico.

Thor Corp.'s Allied Paper Mills division has optioned 122 acres east of New Castle, Colo., for a proposed pulp mill.

Allegheny Ludlum Steel Corp. has just completed a year's modernization program at its Buffalo plant which is devoted to the casting of stainless steel and other high alloy products.

Du Pont Co. of Canada, Ltd., is building an $8-million plant to make Orlon acrylic staple fiber at Maitland, Ont. Completion is set for mid-1957.

Kendall Co. is tripling production capacity for polyethylene protective tapes with a new $1-million plant in Franklin, Ky.

Continental Oil Co. plans a $3-million expansion of its Ponca City, Okla., refinery. Additions include a catalytic reformer and auxiliary facility with a total capacity of 11,000 bbl./day. Completion is set for mid-1957.

Flintkote Co., New York, plans a $20-million program covering expansion of production facilities, new products and the possible acquisition of new business.

Beckman Instruments, Inc., will build a $300,000 manufacturing plant in Munich, Germany.

THE SHORTAGE OF SCIENTISTS AND ENGINEERS:

How Critical Is It?

The United States is running into a serious shortage of scientists and engineers. There is no novelty in this observation. It has often been made in the last few years. And there has been mounting alarm about what this shortage may mean for both our national security and our prosperity.

There would be great novelty, however, if general agreement were attained on such important matters as the size of the shortage, the extent of the damage it threatens to inflict, and the best ways to eliminate it. The purpose of these editorials is not to provide this novelty, but to ventilate some of the key aspects of the shortage of scientists and engineers.

This first editorial in the series is designed to throw light on the over-all dimensions of the shortage. Others to follow will be addressed to such questions as:

- How serious is the threat to our economic well-being and to our national security?
- What needs to be done to prevent the shortage from becoming critical?

Rise Has Been Rapid

The problem is *not* that we have been producing a small number of engineers and scientists. Indeed, the number has risen sharply. We now have a working force of more than 600,000 engineers, over twice as many as the 286,000 there were in 1940. And we have about 250,000 scientists (chemists, physicists, biologists, geologists, mathematicians, etc.), compared to only 92,000 in 1940. About one in 148 persons in the labor force of 1940 was a scientist or engineer; today the ratio is about one in every 80.

In research and development work, where highly creative scientific minds are required, there has been fully as rapid a rise in employment of scientists and engineers. Fewer than 90,000 were employed in research and development fifteen years ago; the total now exceeds 200,000.

—But Not Rapid Enough

Despite this rapid increase in the number of scientists and engineers — at a rate much faster than the increase in the labor force as a whole — the needs of industry, government and education for technically trained people have risen even more sharply.

The principal reason for this mounting demand is the prodigious growth of research in the last 15 years. From a total of only about $900 million spent on all types of research in 1941, the annual expenditure rose to over $5 billion by 1953 (the latest estimate available). Over two-thirds of the research is done by private industry, mostly to develop new and better products and to find new and better methods of production. Most of the rest is performed by the government, largely to develop improved and inevitably more complex scientific weapons.

One aircraft company has found from its own experience that it required 17,000 engineering manhours to develop a typical fighter plane in 1940. The requirement is now about 1.4 million engineering manhours. Development of the typical fighter plane of 1960 will require well over 2 million engineering manhours.

In this dramatic example, the need for engineering services for a basic piece of military equipment soared 80 times in 15 years. It is an indication of why the demand for more and more technically trained men and women has outstripped even the imposing increase in scientific and engineering manpower of the last decade and a half.

Size of the Gap

Exactly how great the gap is between the available supply of scientists and engineers and the number required, it is impossible to say. In some instances technical talent undoubtedly could be better used than it is now. And part of the shortage might "disappear" if higher salaries had to be paid. (These questions will be discussed in later editorials.) But informed estimates of the approximate size of the gap can be given.

- According to the best available information, from estimates by the Engineers' Joint Council and the U. S. Bureau of Labor Statistics, **the minimum need for engineers from graduating classes is 40,000 each year for the next ten years.** Last year we graduated only 23,000 engineers, just about enough to cover replacement needs without allowing for any expansion of the number of active engineers. Projections made by the U. S. Office of Education indicate that we shall probably not have a class of 40,000—the *current* annual requirement —until 1963.
- According to Dr. Howard Meyerhoff, executive director of the Scientific Manpower Commission, **there is now a shortage of about 20,000 scientists.** Last year the number of doctoral degrees in the natural sciences, almost a prerequisite for research work, was only 5,000. Dr. Meyerhoff estimates that the shortage of scientists will rise another 30,000 by 1960.

More Needed As Teachers

Not all of the graduates with scientific and engineering training, furthermore, will work as scientists and engineers—that is, by performing research and giving it practical application. Such training is now necessary in many sales and management positions. And more of our technically trained men and women must remain in educational institutions as teachers if the quality of engineering and scientific education is to be maintained. A survey in 1954-55 by the National Education Association showed that, out of 277 universities, state colleges and large private colleges, nearly one-third *already* had unfilled vacancies in engineering and three-fourths had vacancies in physical sciences.

The dimensions of the shortage of scientists and engineers can be summarized as follows: **Despite a substantial rise in the trained manpower available, the needs of industry, the government and education have risen still faster. The best information indicates that, on the basis of current and anticipated needs, our recent yearly rates of production of slightly over 20,000 engineers and about 5,000 PhD's in natural sciences could be doubled without closing the gap entirely.**

The disturbing implications of this shortage for our national security and our prosperity and some practical suggestions for eliminating it will be the subjects of subsequent editorials in this series.

This is one of a series of editorials prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nationwide developments of particular concern to the business and professional community served by our industrial and technical publications.

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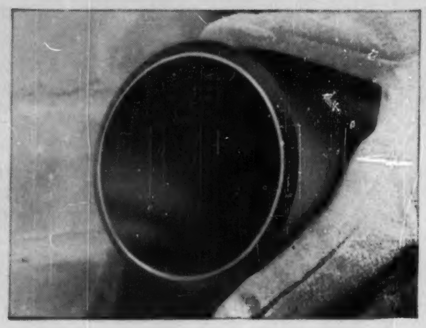

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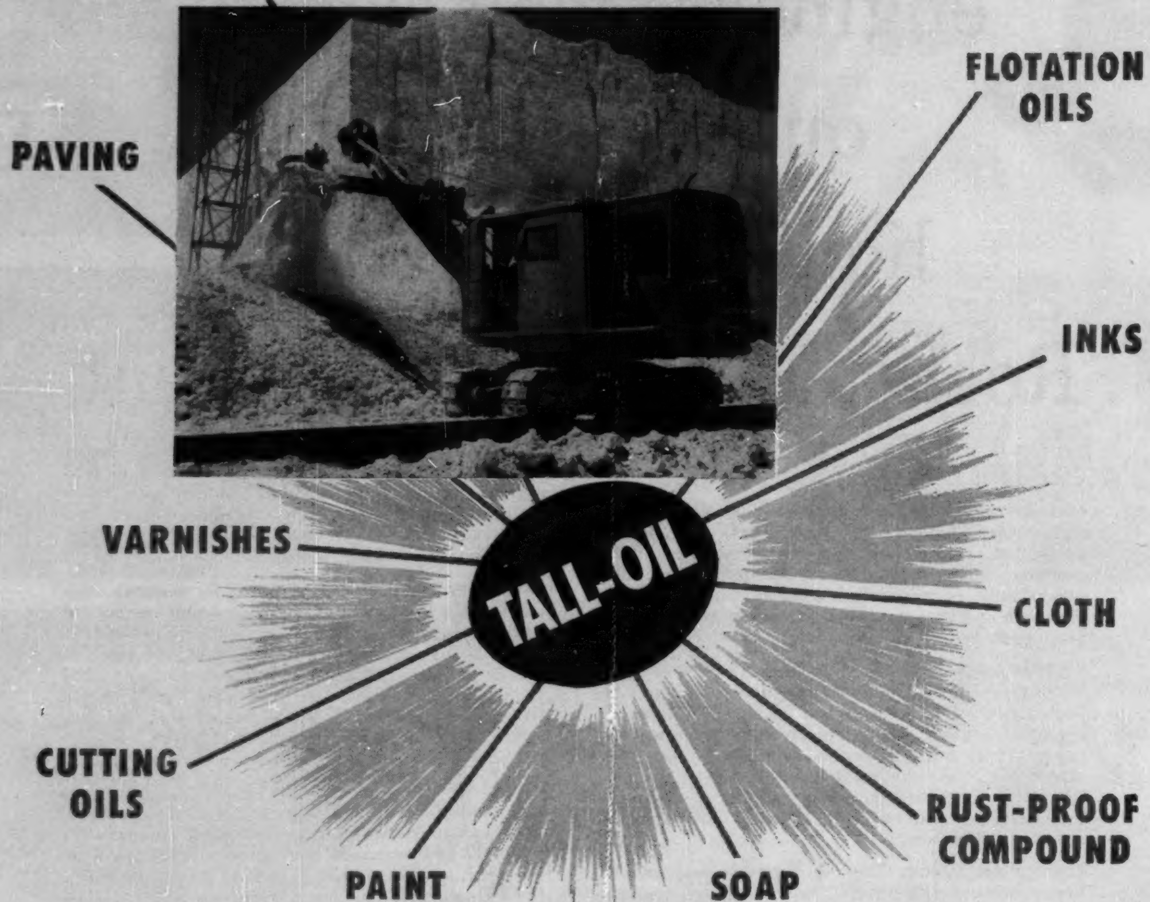
helps to create HEADLINE products



New uses are popping up everyday for this refugee from the skimmings of kraft mill black liquor. Tall Oil is fast becoming the antidote to a lot of supply shortage headaches and cost problems.

That Tall Oil is extracted from black liquor skimmings with the aid of sulphuric acid is perhaps not as interesting as the fact the process is carried on at subzero (centigrade) temperatures with highly concentrated acid. Most applications of sulphuric are at room temperature or higher.

Here is a relatively new product, certainly a 'headline' product and it requires a derivative of Sulphur in the reactions that make it!

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Sulphur Producing Units

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6200 unplasticized PVC (type I)

DUCT SYSTEM

Steel duct work failed to last beyond one year under the severe corrosion conditions in the chrome and nickel plating departments of one of Connecticut's largest manufacturing plants.* The system was then replaced with BOLTARON 6200 unplasticized PVC. Now, thanks to BOLTARON, the duct system provides maintenance-free, corrosion-free service with a life expectancy well in excess of materials previously used.

Corrosion and system maintenance no longer a problem. BOLTARON 6200 unplasticized PVC is the finest Type I PVC obtainable. It has outstanding resistance to corrosive gases and liquids, alkalies and acids. It's abrasion-resistant too. BOLTARON 7200 high-impact PVC is available when application conditions permit the use of a Type II PVC. Whatever your needs — an exhaust system, acid piping or machined parts, BOLTARON meets your needs.

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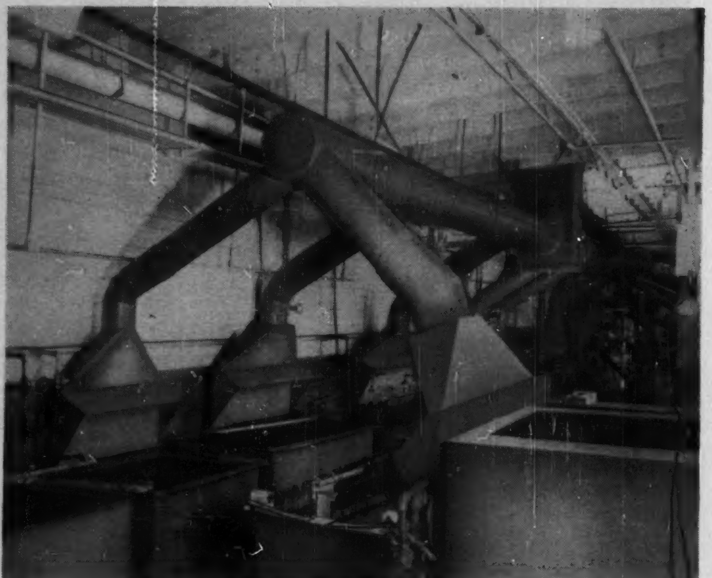
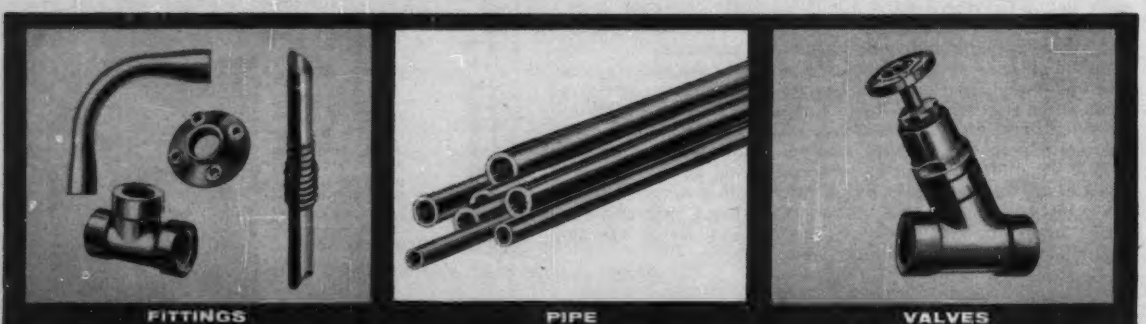


BOLTARON 6200 fabrication installed by the New England Rack Company, Hamden, Conn., fabricators for BOLTARON 6200 and 7200.

The only integrated source for Unplasticized PVC Materials

To insure a uniformly effective system throughout, H. N. Hartwell also stocks a complete line of BOLTARON 6200 and 7200 PVC pipe, valves, conventional fittings and can custom fabricate additional components to meet your specifications.



Conventional fittings, shrink fittings* and roll-thread fittings in full variety of sizes.

A complete line of PVC pipe from ¼" to 6" in schedules 40 and 80.

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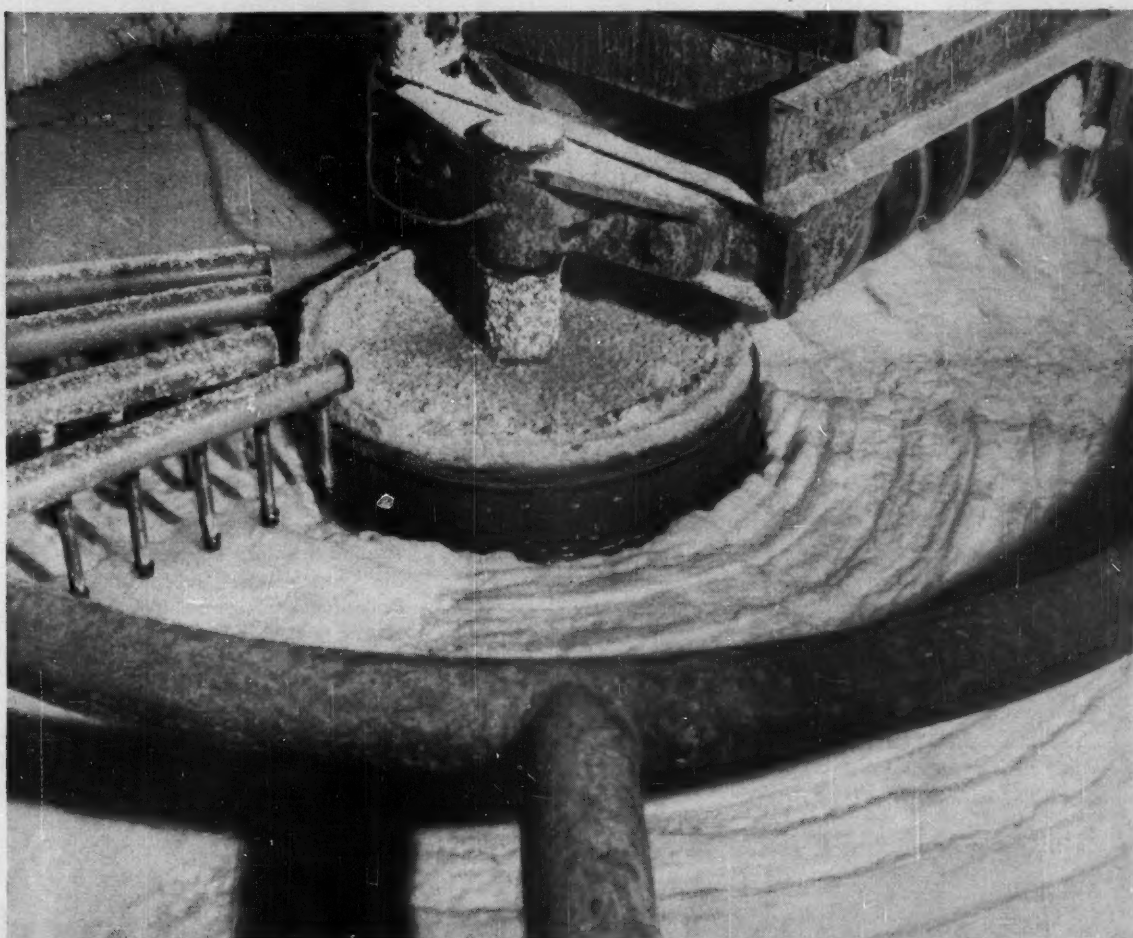
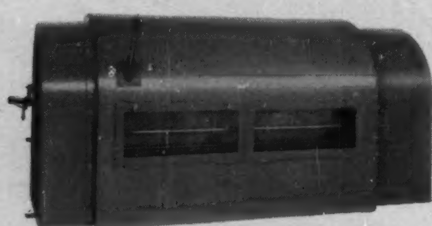
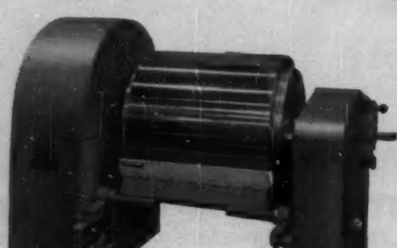
* Patents applied for



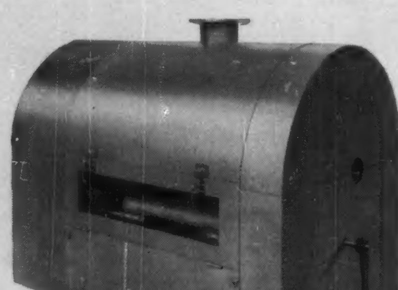
A Stokes flaker used by Tennessee Eastman Company in the production of Tenamene 3 inhibitor.



Around-the-clock operation of this Stokes flaker produces 35 tons daily of an organic resin. Total enclosing of 2½ ft. by 6 ft. unit eliminates dust and fume hazard.

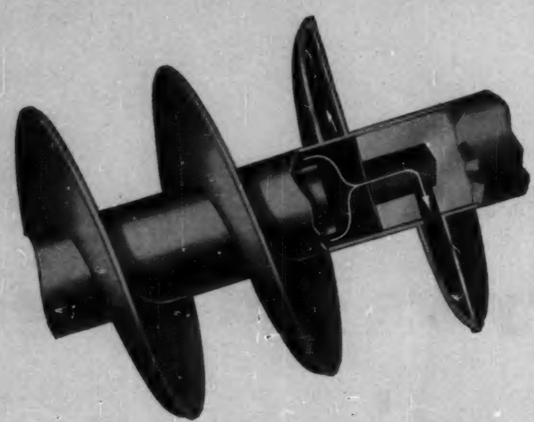


600 pounds per hour of a petroleum-base wax with a melting point of 180F is flaked on this 24" by 24" Stokes machine.



Uranium slurry is processed at a rate of 250 pounds of dried material per hour . . . with this Stokes totally enclosed, 24" by 24", single drum dryer.

A great new advancement in heat exchangers...



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Do you have processes where slurries, solids, pulps or pastes must be cooled or cooked? Do you know you can now handle such processes—*in continuous flow*—in as little as 1/5th the space required by other types of heat exchangers—and with many other important advantages?

The newly-developed HOLO-FLITE Processor is the answer!

what IT IS!

Basically the Holo-Flite consists of two or more flights of hollow-bladed screw conveyors. The product to be processed moves in a trough around the conveyor screws. The heat-transfer fluid circulates through the hollow blades and shafts of the conveyor. The product is constantly rotated into, around, under and over the blades and shafts through which the heat-transfer fluid is circulating, assuring quick, uniform heat passage between the two mediums—*as the product is continuously moved along in a bulk-flow without interruptions!*

Get the complete story on Holo-Flite savings and how this new advancement can simplify your processing operations. It is backed by the same organization that pioneered Cottrell Precipitators and Multiclone Collectors—your assurance of complete dependability.

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why IT'S BETTER!

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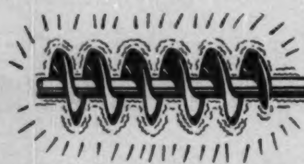
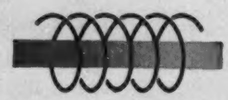


ITS LARGE HEAT-TRANSFER SURFACE requires far less space—as little as 1/5th the space required by other heat-exchange equipment. Further, flights can be "stacked" as high as desired to save floor space, simplify installation!



ITS SLOW ROTATION IS SO GENTLE that granular and powdered solids are handled with no dusting—little or no particle abrasion. Result—no dust recovery problems . . . simple, inexpensive installation.

IT IS ADAPTABLE to a wide range of applications—handles solids, pulps, pastes and slurries with equal ease. Heat transfer agent can be refrigerant, water or other fluids to provide a wide range of temperatures. Cooled products can be packed directly from HOLO-FLITE discharge, saving time, space and additional handling.

IT CAN BE DESIGNED to handle virtually any capacity by varying the diameter and length of the flights, and the number of "tiers."

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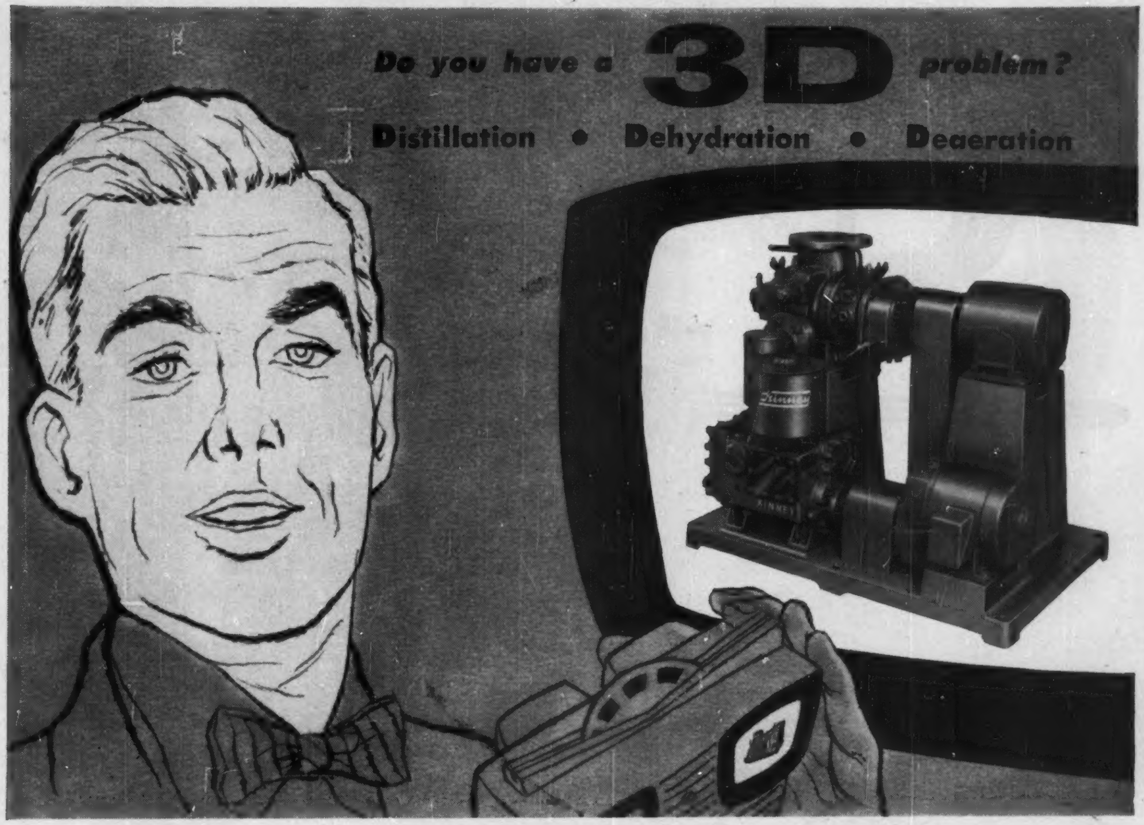


Kinney's new KMB-230 is the answer!

The latest addition to Kinney's Mechanical Booster Vacuum Pump family, the Model KMB-230, is a smaller version of the popular Model KMB-1200 . . . and provides the chemical industry with a pump ideally suited for distillation, dehydration, deaeration, and other production applications. The KMB-230 . . . backed by a Model KC-18 for roughing out purposes . . . swiftly, accurately, and consistently creates and maintains the desired vacuums . . . with the same application versatility, thorough dependability, and low maintenance requirements characteristic of the entire Kinney line. Check these specification data!

- **Ultimate Pressure (McLeod Gauge)** .... **0.1 Micron**
- **Free Air Displacement** .... **230 CFM**
- **Motor H.P.** .... **2 and 1**
- **RPM** .... **3600 and 640**
- **Oil Capacity** .... **5 pints**
- **Cooling** .... **Water**
- **Shaft Seal** .... **Mechanical**
- **Shaft Diameter** .... **¾ and ¾**
- **Inlet Connection** .... **4" Flanged**
- **Outlet Connection** .... **1¼" Screwed**
- **New Weight, Complete** .... **1010 pounds**

Request complete data or contact one of our competently staffed district offices for a speedy solution to your particular vacuum problem. District offices are located in Baltimore, Charleston, W. Va., Charlotte, Chicago, (La Grange), Cleveland, Detroit, Houston, Los Angeles, New Orleans, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis — The International Sales Office, 90 West St., N. Y. 6. Call or write us today!

KINNEY MFG. DIVISION
THE NEW YORK AIR BRAKE COMPANY
3551 WASHINGTON STREET • BOSTON 30 • MASS.
INTERNATIONAL SALES OFFICE, 90 WEST ST., NEW YORK 6, N.Y.

- PLEASE SEND BULLETIN V54 describing the complete line of Kinney Vacuum Pumps.
- Our vacuum problem involves ____________________

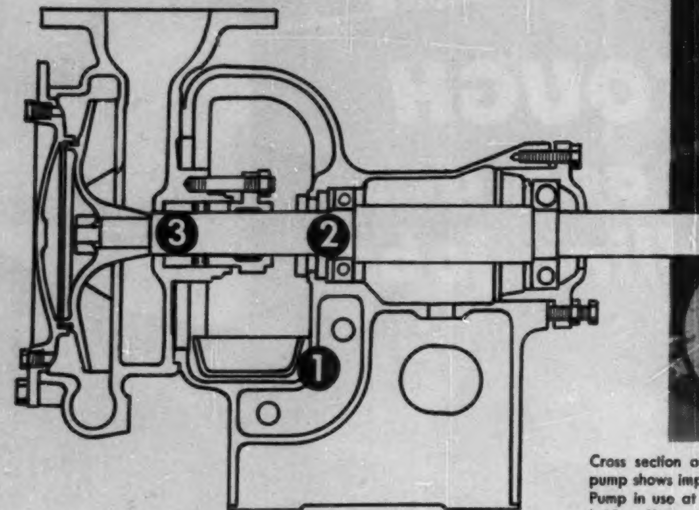
____

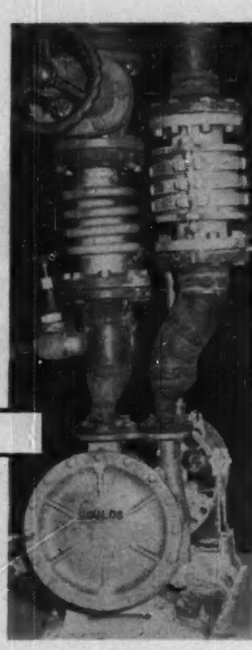
Name ____________________

Company ____________________

Street ____________________

City ____________ *State* ____________





Cross section of Goulds Fig. 3715 chemical pump shows important design features. (Right) Pump in use at Lever Brothers plant at Cambridge, Mass.

How Lever Brothers pumps caustic soda up to 350° F. safely and economically

Corrosive acids and harsh alkalies like caustic soda soon eat the heart out of an ordinary pump.

Lever Brothers handles tons of hot caustic every day, making such well-known soaps as Lux, Lifebuoy, and Rinso.

To get the hot caustic from tank cars to storage, and to move it from tank to tank within the plant, Lever Brothers relies on the Goulds Fig. 3715 chemical pump.

Designed especially for handling hot, corrosive and abrasive liquids, this centrifugal pump has a number of features that give you safer, longer, more dependable performances:

Metals to fit the task. Because different metals are more resistant to corrosion by different chemicals, the Fig. 3715 pump is stocked in type 316 stainless steel, Gould-A-Loy 20 (equivalent to ACI CN 7M CU), all bronze, bronze-fitted, all iron, and iron or bronze with stainless steel trim. Still other metals can be supplied on order.

Cooling for hot liquids. The pump has a water-cooled support head (1), a quenching gland (2), and a water-cooled stuffing box (3). Pump can be changed from stuffing box to single or double mechanical seal construction on the job.

Easy to clean and inspect. You can clean and inspect the pump or replace its impeller without disturbing pipe connections. Axial clearance between impeller vanes and casing can be adjusted externally. Completely sealed bearings keep out dirt and moisture, are grease lubricated.

No leakage. Stuffing box is on suction side of impeller, gets suction pressure only, holds leakage at a minimum.

There are 9 sizes of the Fig. 3715 pump providing capacities up to 720 GPM, heads to 200 feet.

For more information on sizes, including specifications and performance curves, write for Bulletin 725.4.

If you would like to see the pump's features in your own office, we can arrange to show you a small-scale aluminum model.

Caustic soda going into these famous Lever Brothers products is handled safely, dependably by Goulds Fig. 3715 chemical pumps.

Goulds chemical pump handles hot fatty acids in an oil processing plant. Water-cooling and quench gland protect pump from hot acids and alkalies.

Goulds chemical pumps circulate hot size in textile plant. Pumps were especially designed to handle hot, corrosive and abrasive liquids.

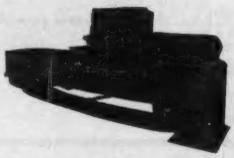
MEMBER

Goulds PUMPS INC. Seneca Falls New York

Sales Offices: Atlanta • Boston • Chicago • Houston New York • Philadelphia • Pittsburgh • Tulsa

WHERE TO BUY

Featuring additional Equipment Materials, Supplies and Service for the Process Industries



FEED MATERIAL BY WEIGHT

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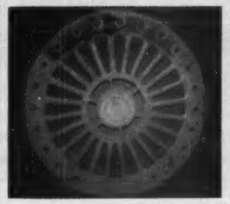
MERRICK FEEDOWEIGHT

MERRICK SCALE MFG. CO.
171 SUMMER ST., PASSAIC, N. J.

Make it a
HABIT . . .
to check this page—
EACH ISSUE
THIS WHERE TO BUY SECTION supplements other advertising in this issue with these additional announcements of products and services essential to efficient and economical operation in the process industries.
CHEMICAL ENGINEERING



RUBBER LININGS THAT RESIST CORROSION

Acme Fisher corrosion-preventing rubber lining and covering can be applied to almost anything. You can depend on getting the correct formulation to provide the highest degree of protection and at the correct price.

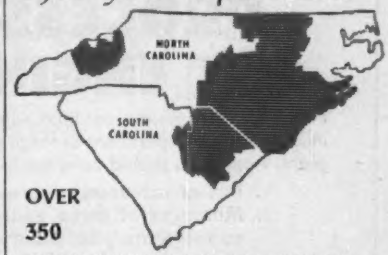
Write for price list on rubber lined pipe and fittings. For special jobs write, wire or call for quotation.

Acme Fisher Division

Broadway Rubber Corporation
Louisville, Ky.

TANK-O-METER
FOR MEASURING TANK CONTENTS ANY DISTANCE AWAY
ANY LIQUID
Uehling
INSTRUMENT CO.
491 GETTY AVENUE, PATERSON, N. J.
SEND FOR BULLETIN 945

THE RIGHT LOCATION
for your operation



OVER
350
COMMUNITIES TO CHOOSE FROM
Address S. P. Vecker, Vice President Area Development Dept.

Carolina Power & Light Co.
RALEIGH / NORTH CAROLINA

EMPLOYMENT OPPORTUNITIES

CONTINUED ON PAGES 472-476

A CONFIDENTIAL SERVICE *for...*

ENGINEERS SCIENTISTS
800 Client Companies
Many Fee-Paid Opportunities in New York, New Jersey, Connecticut

SUBURBAN
EMPLOYMENT AGENCY, INC.
102 Main St., White Plains 8-4800

Offices in Stamford, Conn. and N. Y. C.

CHEMICAL ENGINEERS
An active, confidential service!
Interview at your convenience.
Call, write or wire
GLADYS HUNTING (Consultant)
DRAKE PERSONNEL, INC.
220 So. State St. Rm. 626 Chicago 4, Ill.
HArrison 7-8600

RESEARCH CHEMISTS
$9,000 Per Year

New product development section needs young, aggressive research chemists to develop new feeds and foods. You must have potential to head up new sections as they are created. Excellent opportunity for men now earning $7,500-$8,000. Company pays agency fee and relocation expense.

28 E. Jackson Blvd. Chicago 4, Ill.
Monarch Personnel

REPLIES (Box No.): Address to office nearest you
NEW YORK: 330 W. 42nd St. (36)
CHICAGO: 520 N. Michigan Ave. (11)
SAN FRANCISCO: 68 Post St. (4)
LOS ANGELES: 1125 W. 6th St. (17)

POSITIONS VACANT

Position open for Chemical Engineer between 30 and 40 years of age. Must be capable of supervising all phases of pilot plant operations. Location Southwest U. S. A. Salary open. P-1412, Chemical Engineering.

Engineer immediate opportunity for B.S. Mechanical or Chemical Engineer as Assistant Plant & Maintenance Engineer. Work involves both project and maintenance engineering of a diversified nature. Little or no experience necessary. Prefer young man under 30 years of age. An excellent opportunity for young man to show ability where it will be recognized. Please write—Personnel Department, Davison Chemical Company, 4775 Paddock Road, Cincinnati 29, Ohio.

Assistant Chief Engineer age limit 45. Must be graduate mechanical, chemical or civil engineer with natural mechanical ability, excellent practical and supervisory and some construction experience, for charge under chief engineer of all shops, foundry, mobile equipment including loading, marine, railway and construction; maintenance and repair of all types of equipment; 7200 KVA diesel generating plant. Mine and mill 2600 tons/day. Flotation Mill Copper. Salary open. Foreign. With initial letter send full experience, references, age, marital status, number and age of children. Reply: Cyprus Mines Corporation, 523 West Sixth Street, Los Angeles 14, California.

(Continued on following page)

HELP WANTED

Metallurgists: Company engaged in basic process and pyrometallurgy requires several men for Production, Development and Quality Control who have some experience in one or more of the following: Smelting and Refining, Steelmaking, or Electric Furnace Operation. Excellent opportunities for qualified men. Hospitalization, insurance and pension plan provided by Company. Plants located midwest, north and south. All replies held strictly confidential. Submit detailed resume to

P-1540, Chemical Engineering
330 W. 42 St., New York 36, N. Y.

WANTED
TECHNICAL EDITORS

To provide for its continued growth Chemical Week is seeking two additional assistant editors — preferably chemists or chemical engineers with two to three years business experience. Essential: Ability to meet people, dig out facts, interpret them intelligently and write lucidly. Please submit resume to:

PERSONNEL DIRECTOR
McGRAW-HILL PUBLISHING CO.
330 W. 42ND ST.
NEW YORK 36, N. Y.

EMPLOYMENT OPPORTUNITIES

The Advertisements in this section include all employment opportunities—executive, management, technical, selling, office, skilled manual, etc.

NATIONAL COVERAGE

Positions Vacant
Positions Wanted
Part Time Work

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Send NEW ADS and Inquiries to Classified Advertising Div. of CHEMICAL ENGINEERING, 330 W. 42nd St., N. Y., 36, N. Y.

PROCESS DESIGN ENGINEERS

Permanent responsible positions with opportunity for high calibre men in Engineering Department of large Gulf Coast chemical manufacturing plant. Applicants should have the following qualifications:

1. **B.S. or advanced degree in chemical engineering.**
2. **Minimum of three years experience in process design calculations, pilot plant operations or production trouble shooting—preferably in organic plants.**
3. **Interest in detailed calculations and mechanical-chemical interpretation into practical designs.**
4. **Interest in chemical engineering as a profession.**
5. **Ability to work with others in a team.**

Positions are in Process Design Section for work on new plants and additions to existing plants. Work includes translation of pilot plant processes into full scale plant design, design calculations on distillation, heat transfer, mass transfer, fluid flow, and associated work necessary to prepare flow sheets (no drafting). Processes are both organic and inorganic. Some field data and production equipment performance evaluation involved. Small electronic computer to be available in this work. Assignments will allow for full recognition of individual's ability, with commensurate salary.

Replies held in strictest confidence, all will be answered. Please send complete resume, including education, experience, and salary expected to Mr. D. M. Duguid, Technical Employment Manager.

Texas Division

The Dow Chemical Company

Freeport, Texas

Linde

and

LOW TEMPERATURE ENGINEERING

We have unlimited opportunities for CHEMICAL ENGINEERS in:

- distillation
- heat transfer
- thermodynamics
- fluid flow
- stress analysis
- equipment design
- instrumentation and controls
- pilot plant design and operation
- process engineering
- fabricating techniques

These projects are associated with the production and distribution of oxygen, nitrogen and argon as low temperature liquid or gases.

LOCATION: Our Tonawanda Laboratories in suburban Buffalo, New York—our largest research and development facilities.
B.S., M.S., Ph.D. graduates with up to five years experience are invited to investigate.

LINDE AIR PRODUCTS COMPANY

a Division of

UNION CARBIDE AND CARBON CORPORATION

Send resumes and approximate academic standing to:

Mr. P. I. EMCH, P. O. Box 44

Tonawanda, New York **Refer to ad: CEG-L**

HEAT EXCHANGE ENGINEER

WITH REFINERY & CHEMICAL PLANT EXPERIENCE

APPLY
OR
SEND RESUME TO

PARSONS

617 So. Olive
Los Angeles 14, Calif.

POSITIONS VACANT

(Continued from preceding page)

Graduate Engineers, Preferably chemical for both headquarters consulting and field sales work. For sales, should have 3 or more years successful record. For consulting, young men preferred so that our business can be taught and they can move up. Write P-9197, Chemical Engineering.

Chemical Engineer—or Chemist with mechanic interest or background for pilot plant and process development work. Will work with packaging problems, formulate techniques and chemical synthesis. Send resume to P-1530, Chemical Engineering.

Executive Vice President Needed unusual opportunity in a dynamic small company, making and selling certain exclusive measuring and control devices for chemical and food processing industries. Outstanding profit sharing possibilities. Applicant should be a chemical engineer with breadth of experience and with sufficient enthusiasm to later invest in the enterprise. Right man can become president in a few years. Write P-1648, Chemical Engineering.

Patent Attorney Major Oil Company is seeking a patent lawyer with chemical background, and several years patent experience. If you are now earning in the neighborhood of $10,000, and are ready to step up, send a resume of your personal history, education and experience, in complete confidence, to Mr. H. M. Overley, P.O. Box 7258, Phila. 1, Pa.

EMPLOYMENT SERVICES

Salaried Positions $5,000 to $35,000. We offer the original personal employment service (established 46 years). Procedure of highest ethical standards is individualized to your personal requirements. Identity covered, present position protected. Ask for particulars. R. W. Bixby, Inc., 553 Brisbane Bldg., Buffalo 3, N. Y.

POSITION WANTED

Chemical Engineer: B.S. Ch.E. 1953. Age 30. Family. Veteran. Desires to relocate with company offering responsible position. Experience includes organic chemicals manufacture and petroleum field. Present income $8000. PW-1596, Chemical Engineering.

DEVELOPMENT CHEMIST, CHEMICAL ENGINEERS, AND MECHANICAL ENGINEERS

who are aggressive, ambitious, and are looking for opportunities in an expanding organization, will be interested in locating in our South Carolina Plant—three to five years experience in the specific fields listed below required.

Chemists —For synthesis of phenolic and melamine resins for use in high pressure laminates.
With MS or PhD for advanced development of phenolic, melamine, polyester and epoxy resins.

Chem. Engineers—Molding, laminating, tube rolling from phenolic treated materials.
Polyesters: loaded roving, preforming, molding compounds, and plate.
Process engineering in the laminating and molding field.

Mech. Engineers—Design and modification of equipment for automation of existing processes.
With a chemical background for design development for the application, fabrication, and manufacture of decorative laminates.

We offer the above positions to alert engineers who desire an opportunity to prove their ability for advancement. Salary open—Send complete resume with salary requirements to:

Charles B. Leape, Westinghouse Electric Corp.
Micarta Division, Hampton, South Carolina

DIRECTOR OF ENGINEERING

We are seeking a Director of Engineering. The blueprint of his specifications includes: "Education as an engineer. Age 35-45. At least 10 years of progress through the engineering departments of a medium-sized, or larger, packaged-processed-product (chemical or food rather than "hard" goods) manufacturer employing the most modern production techniques. Present or very recent position—chief engineer or his principal assistant with a salary of at least $12,000 a year with a company in the food, drug or allied product field. For at least the past 5 years, responsibility for all new construction and equipment, as well as other engineering functions. A record of real accomplishment, rather than a potential for accomplishment."

The salary potential is a minimum of $20,000; headquarters, Mid-Atlantic seaboard; environment, city, with a minimum of travel; potential employer, company with most modern plant in its industry.

If you are interested and can meet the qualifications stated, reply stating your present position, your education, your experience in brief resume form, full personal statistics and a brief description of that achievement you most esteem that contributed to your progress. Your reply will be kept most confidential, and any interview resulting is to be kept in strict confidence by you as well.

P-1409, Chemical Engineering
330 W. 42 St., New York 36, N. Y.

CHEMISTRY RESEARCH OPPORTUNITIES IN TEXAS

Challenging opportunities for research chemists in an expanding group now working in physical, analytical, organic, and inorganic chemistry, petrochemistry, biochemistry and catalysis.

Men with initiative, ideas and versatility, plus broad educational background and industrial experience in these fields, will be offered long-range opportunities to develop programs along lines of their own experience and interests in a rapidly growing industrial research institution.

Write
SOUTHWEST RESEARCH INSTITUTE
P. O. Box 2296
SAN ANTONIO 6, TEXAS
Attention S. J. Keane
Manager, Technical Services

DIRECTOR OF TECHNICAL PUBLICITY
WANTED

Growing industrial agency wants engineer with technical editorial experience. Will head up new editorial service department, work with clients' technical personnel and with editors to develop articles for publication; also some field trips. Future is what you make it. Excellent opportunity to get in on ground floor.

W. L. TOWNE ADVERTISING
10 East 40th Street, New York 16, N. Y.

Representative for Chicago District

By a well-known, established concern manufacturing chemical process equipment, such as liquid and dry mixers—ball mills—extrusion and agglomeration machinery. This is an excellent account, so representative must be high-grade, very active, and familiar with the chemical process and similar industries.

Reply to

International Engineering, Inc.
Box 973, Dayton, Ohio

CHEMICAL—ENGINEERING—PROGRESS PATENTS

Petroleum company has the following positions available in Cleveland, Ohio, in a small but expanding patent division of a research- and patent-minded organization:

1. Patent attorney with sufficient experience in chemical applications to work with minimum supervision in preparing and prosecuting applications before the Patent Office and proceedings in which they may become involved.
2. Chemist or chemical engineer with at least B.S., recent graduate, as trainee in patent division. Night law school available with generous company contributions towards law school courses.
3. Chemist with some research background for work with research division in liaison with patent attorneys. Some experience in this area essential, and preferably in the petroleum industry.

THE STANDARD OIL CO., (Ohio)

Reply to:

D. S. Turner, 1737 Midland Bldg.,
Cleveland, Ohio

Opportunity for Two Chemical Engineers
Chief Chemical Engineer
Assistant to Plant Manager

Each of these positions—the first in a staff capacity and the latter in a line function—offers a challenging and remunerative future to the right man. The Chief Chemical Engineer (age 35-45) will be located in New Jersey and the Assistant To Plant Manager (age 30-40) in Ohio. Salary on both jobs is open. Requirements are: About 10 years' experience in organic chemicals preferably fatty acids, plasticizers, etc., thorough knowledge of manufacturing processes, costs, process development, plant maintenance, equipment selection and in the case of the Assistant To Plant Manager—operating experience. All replies will be treated in confidence. If you think you are the right man, write to us giving complete resume. We think these are real opportunities.

Wallace & Tiernan Incorporated
P.O. Box 178
Newark 1, New Jersey

Procter & Gamble needs CHEMICAL ENGINEERS

(Graduated within last 10 Years)

- Permanent positions in Chemical Process Equipment Design and Application and other Engineering Fields.
- Salaries commensurate with education and industrial experience.
- Opportunities to grow with a leading chemical processing company—rated as one of the nation's three best-managed companies by the American Institute of Management.

For application form and further information write

Mr. J. E. Gale
Head of Employment
Engineering Division
The Procter & Gamble Company
Cincinnati 17, Ohio

DEVELOPMENT WITH - - - *Linde*

Our expanding program offers challenging opportunities to graduate CHEMISTS and ENGINEERS who have imagination and creative ability. Projects include MARKET RESEARCH and DEVELOPMENT on such materials as:

- **LIQUID NITROGEN**
  - indefinite preservation and processing of biological materials
  - application of liquid nitrogen temperature in the shipment of frozen foods without intransit refrigeration
  - application of extreme pressures and low temperatures
- **MOLECULAR SIEVE ADSORBENTS**
  - catalysis and hydrocarbon separation
  - process development and plant design

The magnitude and diversity of LINDE products and processes are appealing to technical men who are seeking employment with a dynamic company of proven stability.

Bachelors, Masters and Ph.D's are invited to investigate.

If interested submit resume covering education (approximate academic standing), experience and background to:

LINDE AIR PRODUCTS COMPANY
a division of
UNION CARBIDE AND CARBON CORPORATION
P. O. Box 44, Tonawanda, New York
Attention: Mr. P. I. Emch
Refer to ad: CEG-D

ASSISTANT TO MANAGER FIN-TUBE COIL SALES

A leading manufacturer in the fast growing air conditioning industry has a permanent career opportunity for a graduate engineer who wishes to develop capacity for executive responsibility in engineering, sales and administration. The Trane Company, manufacturers of air conditioning, heating, ventilating and heat transfer equipment, is seeking a young engineer with preferably two or three years experience with heat transfer equipment and/or fluid flow.

Position offers opportunity of advancement with key department in rapidly expanding concern. Work away from crowded industrial areas and live in a congenial medium-sized community located in the heart of a Midwestern vacationland.

Send detailed resume of education, experience and salary desired to

Manager of Staff Employment
THE TRANE COMPANY
LaCrosse, Wisconsin

ENGINEERS
RESEARCH and DEVELOPMENT

Excellent Opportunity for Advancement in Expanding Technical Activities

CHEMICAL or METALLURGICAL ENGINEERS

BS or MS or PhD with 3 to 15 years experience in any of:

Chlorine or fluorine and sulphate chemistry or metallurgy

Electro-Chemistry or Electro-Metallurgy

Production and use of powdered metals (Cermet experience helpful)

Research and development problems related to ore treatment and production of lead, zinc, copper and by-products and alloys

PHYSICAL CHEMIST or METALLURGIST

BS, MS, PhD or equivalent with 10 to 25 years experience in non-ferrous (probably copper) metals and alloys to organize and direct research and development in improvement of copper and its alloys

Compensation and benefits excellent
Recognition for outstanding progress

Send complete resume including salary requirements to

F. H. Beardsley
THE AMERICAN METAL COMPANY, LIMITED
61 Broadway, New York 6, N. Y.

YOU'RE ON THE RIGHT TRACK...

for satisfaction and economy

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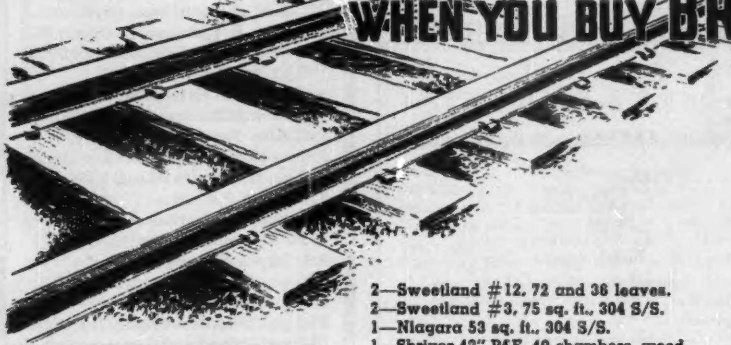

DRYERS

3—Vulcan 6'x60' Rotary Kilns.
2—Vulcan 6'x40', 4½'x50' Rotary.
1—Link Belt 5'2"x20' Roto-Louvre.
4—Devine #27 double door Vacuum Shelf, 17—59"x78" shelves.
1—Devine 5'x10' Rotating Vacuum.
3—Buflovak double drum 42"x120", 42"x90", 32"x90".
2—Hersey 3'x15', 1½'x12', 304 S/S.

FINAL LIQUIDATION

Baton Rouge, Louisiana

1—I.R. Jet Refrigeration Unit complete 208 tons 65° to 60°F.
1—Patterson 7'6" Conical Blender rubbed lined.
1—Buflovak 6'x5'6" Monel Drum Flaker, NEW.
1—Pfaudler 250 gal. Hastelloy "C" Reactor.
3—4'x13' closed 316 S/S Reactors, 109—3'6", 316 S/S tubes, 150 psi.
1—2500 gal. 316 S/S jacketed Reactor.
1—Pfaudler 5'x18" Horiz. glass lined 2500 gal.
1—7500 gal. 316 S/S clad 12'x6'x 5'6" cone.
3—Link Belt 316 S/S 18"x12", 18"x 10', 18"x7' Twin Conveyors.
200 ft. 18" Troughing Belt Conveyor with housing.

FILTERS

2—Oliver Rotary, Monel 8'x10', 3'x2'.
1—Feinc 5'x7' S/S Rotary Vac.
1—Feinc 5'x3' Monel, Rotary Vac.
3—Emico 18"x24", 18"x12", 316 S/S Rotary Vac.
2—Sweetland #12, 72 and 36 leaves.
2—Sweetland #3, 75 sq. ft., 304 S/S.
1—Niagara 53 sq. ft., 304 S/S.
1—Shriver 42" P&F, 40 chambers, wood.
3—Shriver 30" P&F, 36 chambers, iron.

PULVERIZERS—CRUSHERS

2—B&J #1½, #2 Rotary Cutters.
4—Hardinge Mills 4½'x16", 6'x22", 7'x36".
1—NEW Patterson 6'x8' porcelain Pebble Mill 50 HP.
1—National 6"x12" Plastic two-roll Mill.
2—Mikro Pulverizes #2TH and Bantam.
8—Jeffrey 24"x20", 18"x12", 15"x8" Hammermills, NEW.

CENTRIFUGALS

2—Bird 40" Suspended, 347 Stainless, XP motor.
1—AT&M 40" Suspended, steel.
1—Bird 40" Suspended, rubber.
3—Tolhurst 40", 32", 26" Suspended, steel.
1—AT&M 36" center-slung, rubber.
1—Fletcher 30" center-slug S.S.
1—Fletcher 20" Suspended, 304 S/S.
2—Bird 32"x50", 36"x50 steel, solid bowl Continuous.
2—Bird 24"x38", 18"x28" S/S Solid Bowl, Continuous.
2—Sharples #C-27, #C-20, S/S Super-D-Hydrators.

SCREENS

4—Rotex double and single deck 40"x 120", 40"x84".
3—Robinson single deck 40"x84", S/S.
3—S. W. single deck 40"x84", S/S.

MIXERS

8—Day "Cincinnatus" double arm Sigma Blade 550, 200 and 100 gal.
2—Baker Perkins 100, 50 gal. Sigma Blades, jacketed.
2—Robinson 90 cu. ft. 316 S/S jacketed powder.
9—Steel jacketed Powder, 50, 225, 265, 350 cu. ft.
1—Robinson 4000# steel Powder.
6—Rogers 400 to 3000# Powder.
1—Simpson Intensive Mixer #0.
8—NEW Portable Agitators ¼ to 5 HP.
4—Day, Ross 8 and 50 gal., Pony.

TOWERS—REACTORS CONDENSERS & TANKS

2—8'x12' Vertical Tanks 347 S/S 5,000 gal. ½" shell, 120# W.P.
4—Steel Storage Tanks 10'x40', 10'x30', 8½'x25' Horizontal.
8—Towers 7'x25'6", 347 S/S, 6'x69', 6'x 34', 5'x96', 30"x70', 24"x42', 12"x30', 8"x20'.
1—10,000 Aluminum Storage Tank 10'x 16'x¼" shell, 25# W.P.
4—Foster Wheeler Karbate Heat Exchangers 188 sq. ft.
1—Struthers-Wells 536 sq. ft. S/S Heat Exchanger.
8—Heat Exchangers 1728 and 3500 sq. ft. Admiralty tubes.

LIQUIDATION

Near Longview, Texas
Complete Poly Unit, Built 1950 rated 144 bbl/day

1—Wyatt 30"x70' Stabilizer 160# 30 tray.
30—Brown fintube Exchangers 20 to 140 sq. ft.
2—Perco Reactors 4500 gal. 8'x12', 347 S/S 120#, 1000°F.
1—5'x96' Tower, 40 tray, 135# W. P.
1—7'x30' Propane Tank 250# W. P.
1—6'x34' Vacuum Tower 150#.
1—2'x50' Tower, 24 trays.
2—Convection Furnaces 20 MIL BTU/hr.
12—Welded Storage Tanks 5000, 2000, 1000, 500 bbl.
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Reader Service

A. J. BABKOW, MANAGER C. J. ROHRBACH, EDITOR

JUNE 1956

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Chemicals

Acid, Adipic......Comprehensive 8 p. reference gives physical & chemical properties; principal reactions on the carboxyl & alpha methylene groups; solubility curve & suggested uses; etc. Technical Bulletin 1-12.
365 *National Aniline Div.

Acid Anhydrous Hydrofluoric......40 p. book contains valuable information concerning hydrofluoric acid anhydrous. Provides useful data for those who now use HF, or for those who are contemplating its use.
68 *Harshaw Chem. Co.

Acid, Itaconic......20 p. paper bound, index-type technical bulletin outlines uses & properties of itaconic acid—a versatile organic compound made in commercial volume by fermentation. Request Booklet No. 82.
119 *Chas. Pfizer & Co.

Acid, Muriatic......Features high purity muriatic acid—Hooker White. This special grade muriatic is entirely free or arsenic. Contains .003% or less sulfates, & .0001% or less iron. Technical Data Sheet.
384e *Hooker Electrochem. Co.

Alcohols, Lower......Ethyl Alcohol for detergents or Isopropyl Alcohol for rubbing. Your detergents scrub better and your alcohols rub better when formulated with Enjay Lower Alcohols. Request complete details.
133 *Enjay Co.

Alcohols, Primary Decyl......An important intermediate in the manufacture of plasticizers and diester lubricants for jet aircraft. Useful as a solvent for gums, resins, waxes, oils, fats, and dyestuffs. Bulletin F-8922.
494A Carbide & Carbon Chem.

Aluminum Chloride......Surface area of a solid catalyst, such as aluminum chloride, bears an important relationship to reaction rate. That's why company produces it in 4 different mesh sizes. Full data.
384a *Hooker Electrochem. Co.

Ammonium Bicarbonate......Solvay Ammonium Bicarbonate is a safe, low-cost source of ammonia and carbon dioxide. Makes available detailed technical information in addition to a test product sample.
494B Solvay Process Div.

Anhydrides......New booklet gives uses, physical properties, specifications, test methods, shipping data & constant boiling mixtures for acetic, propionic & butyric anhydride. Send for this "Anhydrides" booklet F-5280.
494C Carbide & Carbon Chem.

Calcium Chloride......2 bulletins offer tables, graphs, applications. Cover properties, use, and control of straight calcium chloride as brine medium in refrigeration and ice manufacturing systems. Bulletins Nos. 4 & 16.
147e *Solvay Process Div.

Calcium Nitrate, Technical......Baker Calcium Nitrate, Tech. in thin flat flakes . . . faster dissolving, uniform purity-lot after lot, controlled water of hydration, easier to handle. Request samples & prices.
369a *J. T. Baker Chem. Co.

Carbonate of Potash......Nialk Carbonate of Potash is supplied in 48% and 52% solutions, and in solid forms as 83.5% to 84% hydrate, and as calcined (less than 1% H_2O. Request data on this new Hooker chemical.
384c *Hooker Electrochem. Co.

Carbons, Metallurgical......New technical bulletin discusses chemical and physical characteristics of metallurgical carbons. Details the grades, elemental contents and available mesh sizes. Bulletin J-35.
494D Barneby-Cheney Co.

Catalysts, Platinum Metals......In many procedures, production control, purity of end product & cost of catalysts are brought to peak efficiency thru use of one of the platinum metal catalysts. See literature.
303 *Baker & Co.

Caustic Potash......Nialk Caustic Potash is available in 45% to 52% solutions, & in the following solid forms as 90% & as 85% (low chloride) material: solid, flake, granulated, broken, crushed & walnut. Full data.
384b *Hooker Electrochem. Co.

Chemicals......Bulletin lists products available from commercial production. Gives commercial products, custom manufacturing, developmental products & research interests. For further information, ask for Bulletin No. 2.
494E Maumee Chemical Co.

Chemicals......The 1956 Fisher Chemical Index lists over 7300 chemicals. It gives structural formulas, formula weights, melting and boiling points, and color-index numbers. Available on request—Catalog 120-C.
494F Fisher Scientific Co.

Chemicals......"Ready Reference to the Chemicals You Live By" is a pocket-size folder which provides a handy, helpful list of Diamond chemicals for quick reference. Copies are available upon request.
494G Diamond Alkali Co.

Chemicals......Valuable reference lists the properties and uses of some 350 of the more than 600 basic industrial, pharmaceutical, and agricultural chemicals currently produced by the Dow Chemical Company. 36 p.
494H Dow Chem Co.

Chemicals, Fine-Industrial ...... 12 p. Price Schedule covers Baker fine & industrial chemicals. Includes: acetic acid, acetophenetidin, barium hydroxide, calcium bromide, calcium chloride, nitric acid, etc.
494I J. T. Baker Chem. Co.

Chemicals, Peroxygen......Becco offers various bulletins on hydrogen peroxide & its properties, persulfates, sodium perborate, peracetic acid, peroxygen compounds, textile bleaching & pulp bleaching.
500 *Becco Chem. Div.

Chemicals, Petrochemicals......Company sets new high standards in petrochemicals—constantly growing demand for purer petrochemicals are met by new Sun Oil petrochemical plants. Technical Bulletins.
494J Sun Oil Co.

Chloride, Cuprous......Used in the manufacture of acrylonitrile, vat dyestuffs, phthalocyanine pigments & special batteries. Company makes available samples, experimental quantities & data sheet.
149 *Baker & Adamson.

Chlorine......Offers valuable technical bulletins: #7-"Liquid Chlorine"; #8-"Alkalies & Chlorine in Treatment of Municipal & Industrial Water"; #11-"Water Analysis"; #14-"Chlorine Bleach Solutions."
147a *Solvay Process Div.

Chlorine Compounds, Organic......Bulletin gives full details on fumigants, solvents and extractants, vapor degreasing, dewaxing, dry cleaning and intermediates. Physical properties and specifications shown.
494K Carbide & Carbon Chem.

Chlorine, Liquid......Presents new 72 p. technical and engineering service bulletin, "The Analysis of Liquid Chlorine and Bleach." Literature contains valuable data, tables, charts and indexes. Bulletin No. 12.
147b *Solvay Process Div.

Di-iso Decyl Phthalate......Recently developed phthalate plasticizer enables you to substantially increase life of your vinyl products—at a volume cost less than that of dioctyl phthalate. Technical literature & samples.
494L Ohio-Apex Div.

* From advertisement, this issue

Contents of This Issue . . .

Dimethyl Sulfoxide......Potential uses include: desulfurization & separation of petroleum fractions by selective solvent action; paint removal; solvent for acetylene & other gases; etc. DMSO Technical Bulletin.
495A Stepan Chem. Co.

Elastomers......Neoprene and Hypalon elastomers are used in improving products and cutting maintenance and replacement costs. Company offers "Neoprene Notebook" and "Facts about Hypalon".
317 *E. I. DuPont de Nemours.

Emulsions, Silicone......Bulletin covering HSC #362 Silicone Emulsion. Well suited to mold release applications where maximum stability and release performance are decired. Bulletin No. 11-118-0-2-56.
495B Harwick Standard Chem. Co.

Epichlorhydrin......New technical information bulletin includes: physical properties; applications; typical reactions; physiological properties; numerous references; etc. Request copy of Bulletin No. F-8862.
495C Carbide & Carbon Chem.

Ethers & Oxides......64 p. reference discusses applications of 32 products including ethylene oxide & propylene oxide. Gives data on physical properties, solubilities, shipping, specifications, etc. Ref. No. F-4764.
495D Carbide & Carbon Chem.

Glycerine......Offers valuable booklets including: "Glycerine Alkyds Tailored to Need" (20 p.); reference on glycerine standards & specifications (8 p.); booklet covering properties & applications (16 p.).
169 *Glycerine Producers' Assoc.

Hexamethylenetetramine......New bulletin reporting on properties & uses of this cyclic derivative of formaldehyde & ammonia. Especially useful in the synthetic resin industry. Request "Hexamethylenetetramine" bulletin.
495E Heyden Chem. Corp.

Hydrogen Peroxide......"Albone", an aqueous hydrogen peroxide solution, is available in grades containing 35% and 50% by weight H_2O_2. Descriptive literature contains information on properties and applications.
495F E. I. du Pont de Nemours

Hydrogen Peroxide......Announces release of a valuable literature reference—an article reprint on formation, manufacture, properties & uses of hydrogen peroxide & other peroxides. Request Bulletin No. 2A.
495G Buffalo Electro-Chem. Co.

12-Hydroxystearin......Describes Castorwax 12-Hydroxystearin...the low cost synthetic wax with valuable plus-features. Includes details of the many uses of Castorwax and formulation information. Technical Bulletin 7.
495H Baker Caster Oil Co.

Molybdenum......"The Use of Molybdenum as a Fertilizer in Australia" is a survey of Australian practice prepared by the Commonwealth Scientific and Industrial Research Organization. Bulletin No. Ag-8.
495I Climax Molybdenum Co.

Nitrogen Fertilizer Solutions......"Arcadian Nitrogen Fertilizer Solutions for Direct Application" discusses and illustrates the compositions, chemical properties, and methods of using these solutions in agriculture.
495J Nitrogen Div. AC&D.

Nitroparaffins......As solvents, the NP's present an unusual combination of properties. Request Technical Data Sheet for details, specifications, properties, uses, solubility tables, etc. plus product samples.
R419 *Commercial Solvents Corp.

Oxides, Chromium......Most stable of the green pigments, unaffected by acids, etc., non-fading. The 4 pure chromium oxides withstand ceramic temperature; the 2 hydrated used for brilliant color. Data & samples.
409 *Williams Colors & Pigments.

* From advertisement, this issue

LITERATURE . . .

Paraformaldehyde......New bulletin reporting on properties and uses of this form of formaldehyde. Important in the synthetic resin industry. Copies of the "Paraformaldehyde" bulletin are available on request.
496A Heyden Chem. Corp.

Phenolic Spheres......The tiny spheres, made of Bakelite phenolic resin and filled with sealed-in gas, can cut crude oil losses as much as 80 to 90 per cent. Request "The Microballoon Layer Reduces Evaporation Losses."
496B Bakelite Co.

Polyethylene . . . . . . Offers new 14 p. brochure describing currently available grades of low molecular weight A-C Polyethylene. Gives actual and suggested end uses for these versatile polymers. Bulletin No. 116.
496C Semet-Solvay Div.

Polyphenyl, Chlorinated . . . . . . Aroclor 1248 is a highly stable chlorinated polyphenyl; does not support combustion up to its boiling range 652° to 725° F.; is non-corrosive. Request technical information.
386a *Monsanto Chem. Co.

Polyvinyl Materials......Products made from Geon rigid vinyl include corrosion-proof pipe, fumes ducts, tanks, trays, materials that can be machined, planed, sawed, drilled, and cemented. Request new bulletin on Geon 8700-A.
12 *B. F. Goodrich Chem. Co.

Propylene Glycol......Comprehensive literature includes applications, physiological properties, specifications, physical properties and solubility data for propylene glycol. Request 16 p. reference, No. F-8738.
496D Carbide & Carbon Chem.

Resin, Coumarone-Indene......The special pale, low-odor coumarone-indene resin . . . prescribed for freeze-thaw stable PVAc emulsion paints . . . features valuable cost-saving advantages. Request samples & data.
159 *Neville Chem. Co.

Resins, Hydrocarbon......Covers properties & specifications of resins & resin solutions & gives many specific formulations & cooking procedures for aluminum vehicles, etc., in Tech. Bulletins 219 & 203.
496E Velsicol Chem. Corp.

Resins, Nylon......Zytel is the du Pont trade-mark for a versatile group of long-chain synthetic polymeric amides exhibiting extreme toughness & strength. Complete data on properties & applications on request.
71a *E. I. du Pont de Nemours.

Resins, Penacolite......New bulletin gives description, typical properties, physical characteristics, applications & storage & handling information on Penacolite Brittle Resins B-1A, B-16, B-22. Technical Bulletin C-6-230.
496F Koppers Co.

Resins, Resorcinol-Formaldehyde . . . . . . Synvaren PLS-R is a "stopped" resorcinol-formaldehyde resin for use with latex in treatment of rayon & nylon for subsequent adhesion to rubber. Bulletin 12-198-0-10-55.
496G Harwick Standard Chem. Co.

Resins, Synthetic......CB-35 offers many advantages over materials now in use, particularly in areas of baking, gas formation, collapsibility & resistance to "over baking." Technical literature & samples on request.
496H B. F. Goodrich Chem. Co.

Resins, Synthetic......New 4 p. booklet includes examples of typical applications with data on flexibility, viscosity, pot life, cure times & available forms. Send for "Scotchcast Resins" booklet today.
496I Minnesota Mining & Mfg. Co.

Resins, Tetrafluoroethylene . . . . . . Teflon tetrafluoroethylene resins used extensively in process industries. Offer chemical inertness, high heat resistance, low-temperature toughness, etc. Properties & applications.
71b *E. I. du Pont de Nemours.

* From advertisement, this issue

Resins, Vinyl Chloride Copolymer......Exon 450 is a vinyl chloride copolymer resin of intermediate molecular weight which may be used in solution resin work. Properties & characteristics in Bulletin No. 13.
497A Firestone Plastics Co.

Silicone Products......Announces release of "1956 Reference Guide to Dow Corning Silicone Products." Products grouped by physical form & cross-indexed by usage. Thoroughly illustrated with charts, tables, graphs, etc.
497B Dow Corning Corp.

Soda, Caustic......Technical & engineering service bulletins cover a wide scope of subjects. Includes: physical & chemical properties, use, handling & storage of caustic soda, soda ash. Bulletin Nos. 5 & 6.
147c *Solvay Process Div.

Soda, Caustic......Wall chart (17" x 23") gives 37 specific, successful suggestions for safely handling solid, liquid & flake caustic soda. Safety recommendations cover first aid measures, protective practices, etc.
497C Diamond Alkali Co.

Sodium Benzoate......In perishable food products, sodium benzoate offers low-cost insurance against bacterial action. For details of this assured protection, request leaflet, "Preserving with Sodium Benzoate."
497D Monsanto Chem. Co.

Sodium Perborate......Becco sodium perborate is widely used for dye development and in the manufacture of powder bleaches, cosmetics, etc. For complete product information, request detailed Bulletin No. 45.
497E Buffalo Electro-Chem. Co.

Sodium Phosphates......Announces availability of a valuable reference, "Sodium Phosphates"—an easy-reading booklet giving a brief yet complete review of technical and commercial aspects of sodium phosphates.
497F Monsanto Chem. Co.

Sodium Sulfate......West End Chemical has doubled its production of sodium sulfate to over 100,000 tons a year. Company makes available on request product samples, prices and freight schedules.
459 *West End Chem. Co.

Sodium Sulfhydrate......Hooker, sodium sulfhydrate dissolves rapidly, even in cold water. There's virtually no sedimentation even after long standing. Available in 90-lb. & 350-lb. drums. Technical Data Sheet.
384d *Hooker Electrochem. Co.

Solvents, Aromatic......Cover a very wide evaporation range. Their individual characteristics satisfy specific requirements in a great variety of formulations. See, "Shell Aromatic Solvents for the Coatings Industry."
497G Shell Oil Co.

Solvents, Chlorinated......14 p. Bulletin furnishes technical information on Diamond chlorinated solvents. Included are: carbon tetrachloride, perchlorethylene, methylenechloride, chloroform, methyl chloride.
497H Diamond Alkali Co.

Surface Active Agents......Emulsifier 1990-A is a cationic surface active agent developed specifically for emulsification of pentachlorophenol. Reference includes physical properties, formulations, etc. Bulletin O-8.
497I Armour & Co.

Surfactant......A series of 8 Igepal CO brands range from the oil-soluble Igepal CO-430 to the extremely hydrophylic Igepal CO-880. Igepal CO-630 lacks odor & is sediment-free. Request booklet on Igepal CO Brands.
273 *Antara Chem.

Surfactants......New data folder on "Tergitol" Surfactants. Describes 7 nonionics and 4 anionics. Information on physical properties, shipping data and specifications. Performance data on wetting and cleaning.
497J Carbide & Carbon Chem.

* From advertisement, this issue

Titanium Dioxide......"The Story of Unitane Titanium Dioxide" prepared for the dedication of titanium dioxide plant at Savannah, Georgia in December. A unique pigment that has raised the quality of objects around us.
498A American Cyanamid Co.

Vitamin B_{12}......A dark red, crystalline powder; practically odorless & tasteless. Uses—as anti-anemia factor in treatment of pernicious anemia, tropical & non-tropical sprue, etc. Technical Information Sheet.
498B Mallinckrodt Chem. Wks.

Zinc Nitrate, Technical......Baker Zinc Nitrate, Tech. in thin flat flakes . . . faster dissolving, uniform purity—lot after lot, controlled water of hydration, easier to handle. Request samples & prices.
369b *J. T. Baker Chem. Co.

Construction Materials

Castings, High Alloy......Covers facilities for producing high alloy static & centrifugal castings & offers data on castings used for resisting high temperatures, corrosion & abrasion. Request Bulletin No. 3150-G.
440 *Duraloy Co.

Coatings, Protective......Describes Amercoat No. 87—a heavy bodied, high solids vinyl resin coating which can be applied at thicknesses up to 10 mils in one coat. General physical & chemical properties detailed.
285 *Amercoat Corp.

Coatings, Protective......Fully illustrated, 25 p. Catalog offers complete information on the anti-corrosion tapes manufactured by Polyken Sales Division. Features success in protection of underground pipelines.
498C Kendall Co.

Coatings, Protective......Atlas produces a complete line of neoprene, vinyl, styrene, epoxy, chlorinated rubber & polyester coatings. They are pioneers in corrosion protection. For further data, refer to Bulletin 7-2.
422 *Atlas Mineral Prods. Co.

Fabrication......Special facilities for the fabrication of pressure vessels, high pressure piping & unusual weldments, custom designed to specification, are described in a new 18 p. brochure. Request Bulletin GS-56-4.
498D Foster Wheeler Corp.

Fabrication, Specialty......Presents fully illustrated brochure of fabricating facilities of a company which specializes in engineering and fabrication of specialty and custom-built equipment. Request Catalog No. 155.
437 *Fritz W. Glitsch & Sons.

Insulation, Pipe......Lower heat losses, lower cost with new Snap*On glass fiber pipe insulation. Available in sizes that will fit pipe from ½" to 33" nominal diameter, inclusive. Request Technical Bulletin SO-55.
371 *Gustin-Bacon Mfg. Co.

Paints, Plastic......"Seal-Kote" paint does not bubble, blister, chip or peel. Its smooth, leathery surface is practically self-cleaning & resistant to stains of oils, greases, fumes & dirt. Bulletin LL-2421.
498E Wooster Sealkote Co.

Paints, Protective......Tygon "ATD" Hot Spray Paint saves you countless hours of "down time." Request the new TYGON Protective Coatings Manual for further information on these paints.
102 *U. S. Stoneware.

Rubber & Plastic Materials......Piping, pumps, valves and tanks have a wide range of temperatures, pressure, impact resistance. For details about Ace rubber and plastic materials, request Technical Data CE-50.
427a *American Hard Rubber Co.

* From advertisement, this issue

Rubber Products......Laboratory facilities for compound developing, fabricating techniques for producing rubber products to close tolerances, & a showing of representative products highlighted in 8 p. Brochure.
499A Goshen Rubber Co.

Steels, Alloy......Here are just three of the various grades offered . . . Altemp A-286, S-816 & S-590. Company makes available certified laboratory data on the properties of their high temperature Super Alloy Steels.
344 *Allegheny Ludlum Steel Corp.

Steels, RubberLined......Ace rubber-lined steel . . . strength & pressures of steel plus chemical resistance of hard rubber. Excellent for alkalis, most inorganic acids, many organic acids, etc. Bulletin CE-52.
426c *American Hard Rubber Co.

Steels, Stainless......16 p. illustrated booklet describes the physical properties and analysis, relative corrosion resistance, fabrication, application and care of MicroRoid Type 430 nickel-free stainless steel sheet.
499B Washington Steel Corp.

Surfacing, Floor......Newest advancement in continuous search for better corrosion-proof materials — offers greater protection than conventional acid-proof floor materials. Brochure & trial sample of Corocrete on request.
417 *Cellcote Co.

Tantalum......Tantalum is immune to hydrochloric acid, nitric acid, bromine, iodine, chlorine and many others. It is strong, immune to thermal shock, unequalled in heat transfer efficiency. See, Tantalum Booklet.
503 *Fansteel Metallurgical Corp.

Titanium . . . . . . Titanium "top-hat" thwarts corrosion damage. Fits snugly into top of condensers. Data on application and fabrication of titanium alloys in descriptive Rem-Cru Review.
60 *Rem-Cru Titanium.

Electrical & Mechanical

Bearings, Roller......New 72 p. Catalog contains specification and data pages on all models of Shafer units. Shaft sizes range from ¾" to 7". Includes new load rating tables and engineering data. Catalog 55.
499C Chain Belt Co.

Belts, V-......Four reels of Veelos adjustable v-belt replace up to 316 different sizes of endless belts—& take up a space of only 16 in. square. Veelos Data Book contains valuable engineering data.
350 *Manheim Mfg. & Belting Co.

Brakes, Magnetic Disc......New through-shaft magnetic disc brake incorporates the advantages of solenoid operation. The design of the unit permits drives off both ends of the shaft. Request Bulletin No. 2802.
499D Stearns Magnetic.

Casters......New 4 p. catalog shows full line of Rapistan casters. Describes exclusive features of Steel Forged, Cold Forged, and Stamped Steel from light to heavy duty, and recommends uses. "Condensed Caster Catalog."
499E Rapids-Standard Co.

* From advertisement, this issue

Now turn to the back . . .

Simply circle the code numbers desired on the handy pre-paid postcard, and mail it to us. Replies will reach you direct from the companies manufacturing the products.

LITERATURE . . .

Expanders, Tube......Announces new General Catalog on tube expanders, cutters & accessories for fire tube boilers, water tube boilers, condensers, coolers & heat transfer units. Request your copy of Catalog 81.
BL453a *Gustav Wiedeke Co.

Fixtures......Appleton vented fixtures offer; "Flame-tight" contact chamber; "Full-circle" venting; "Interchangeable" unilet body; Conversion to different wattages in just 58 seconds. Request complete information.
155 *Appleton Electric Co.

Gaskets, Teflon......The ideal seal for many process applications is a Flexitallic gasket with teflon trapped between edges of stainless steel. For complete data request folder, "Teflon in Flexitallic Gaskets."
404 *Flexitallic Gasket Co.

Motor Units......Rugged in construction and simple in design, Chapman Motor Units insure longer life with fewer repairs. Smooth, accurate and trouble free operation. For details, request Catalog 51.
98 *Chapman Valve Mfg. Co.

Motors......Motors to power your pumps, agitators, compressors and blowers. Offers diversified line of standard motors, from 1/6 to 500 hp, readily adapted to your requirements. For complete information-Bulletin MU-185.
76 *Wagner Elec. Corp.

Motors, Gear......The U. S. Syncrogear Motor is completely described and illustrated in a new 16 p. full-color brochure. Includes: normalized castings, friction-free oil seal & genuine pyramidal design.
373 *U. S. Elec. Motors.

Motors, Pump......16 p. describes hollow shaft Verticlosed grease- and oil-lubricated motors in sizes from 1¼ to 400 hp; also single phase designs up to 7½ hp, & totally-enclosed types up to 150 hp. Bulletin 1903.
500A U. S. Elecl. Motors.

Motors, Weather-Protected ...... Announces the publication of a new reference describing in detail the construction features of Allis-Chalmers weather-protected motors for outdoor installation. Bulletin No. 05B7874B.
500B Allis-Chalmers Mfg. Co.

Packings & Gaskets......8 p. bulletin features a wide variety of R/M Packings & Gaskets made of "Teflon." Includes available sizes & service recommendations. Available upon request —Form. No. 6906.
500C Raybestos-Manhattan.

Seals, Mechanical......Combining chemically impervious teflon with a balanced bellows design—Chemiseal external mechanical seals last longer & give unsurpassed performance. Details in Bulletin No. MS-1155.
431 *U. S. Gasket Co.

Seals, Mechanical, Rotary......Company announces the availability of a new 8 p. reference which shows how you get maintenance-free sealing that slashes fluid mixing cost to a new low. Illustrated Bulletin B-111.
257h *Mixing Equipment Co.

Seals, Selector......The new Sealol Flexibox Sealector enables you to decide on seal type size and materials for your specific requirements. Covers 48 typical products handled in the process industries. Request Sealector.
447 *Sealol Corp.

Seals, Shaft......Type 9 Shaft Seal for corrosive and high temperature services. Teflon wedge shaped sealing member is impervious to chemicals & solvents-permits high temperature service to 500°F. Bulletin S-205-2.
500D Crane Packing Co.

Teflon Products......Illustrated booklet, "The Best in Teflon," covers data on Teflon parts & products—bellows, bellows connectors, pump & valve packings, tubing & other molded forms. 12 p. Chemlon Catalog.
411a *Crane Packing Co.

* From advertisement, this issue

Transmission Equipment, Power......Illustrated, 24 p. describes line of power transmission equipment. Includes; variable speed pulleys; wide v-belts; sheaves; motor bases; countershafts; Select-O-Speed Transmission.
491 •Lovejoy Flexible Coupling Co.

Transmissions, Gear......New 8 p. booklet describes the 7 different models of the company's new Plan-Gear Transmission. Offer 1 or 2 forward speeds & a choice of reverse gear ratios. Request "Plan-Gear Transmission."
501A American Gear & Mfg. Co.

Turbines, High-Speed......Well-designed, efficient seals . . . cut steam leakage . . . reduce maintenance costs of G-E High-speed Turbines. Also feature low-cost, easily-replaced carbon packings. Bulletin GEA-6232.
376 •General Elec. Co.

Handling & Packaging

Acrylonitrile Handling......Issues a Technical Service Bulletin discussing the techniques for safe storage and handling of acrylonitrile. A data sheet insert listing physical properties of the pure compound is included.
501B Monsanto Chem. Co.

Conveyors......The 375 transfer conveyor features: lengths from 8'; widths 18", 24" & 30"; & handles almost any bulk material. Company offers new Folder, showing how you can figure horsepower & belt width.
BL517 •Barber-Greene.

Conveyors, Screw......Link-Belt's sound engineering and quality manufacture assure you of top performance. A 92-page Screw Conveyor Book contains complete ordering data. Request your copy. Book No. 2289.
14 •Link-Belt Co.

Drums, Acid......Seamless chimes of Hackney two-piece acid drums harbor no acid traces between shipments. These drums are rugged & durable. Request Drum and Barrel Catalog & minimum quantity data.
15 •Pressed Steel Tank Co.

Feeders, Rotary Airlock......Illustrated, 12 p. bulletin covers the complete line of Prater Rotary Airlock Feeders. Includes data on selection, features, specifications, dimensions, installation, etc. Bulletin No. P-55.
501C Prater Pulverizer Co.

Loading Arms......Use Chiksan Loading Arms for handling tough corrosives. The time proven answer where the accent is on service, safety and speed. Be sure of maintaining smooth production schedules. Chiksan Catalog.
345 •Chiksan Co.

Materials Handling......If you are presently conveying dry, pulverized materials into, through, or out of your plant, get the full story on Fuller-Kinyon—harnessing air to move materials. Bulletin FK-26A.
380 •Fuller Co.

Slings......Newly revised informative bulletin covers slings varying from ½ ton safe load to 48.7 tons safe load. If you have the problem of lifting loads with overhead cranes and hoists, request Bulletin No. 5308-R.
501D Macwhyte Co.

Sodium Handling......Teflon can be bonded after sodium treatment. If you are using metallic sodium for the first time in this application, request "Handling Metallic Sodium on a Plant Scale."
35-6C •U.S. Industrial Chem. Co.

Tractor-Shovels......The HA "Payloader" & the larger models—to 2½ cu. yd.—do the work of 4 previous units. Ideal for any bulk materials you have to load, dump, stockpile or spread. Request "Payloader" literature.
•Frank G. Hough Co.

•From advertisement, this issue

LITERATURE . . .

Trucks, Hand......New "Hi-Lift Platform" Hand Truck offers load security & fingertip controls while maintenance is made easy. Travels at 3 m.p.h. empty & 2.2 m.p.h. fully loaded. Request details.
502A Clark Equipment Co.

Trucks, Industrial......New Model B-224 Lamson Mobilift Industrial Truck features added maneuverability & increased safety factors. New Mobilift also has double frame construction. Literature upon request.
502B Lamson Mobilift Corp.

Trucks, Lift......Compact new Hyster QN-20 Monomast Lift Truck is claimed to be an ideal "work horse" for both inside & outside production. Offers faster load placement & greater safety. Request Form No. 1452.
502C Hyster Co.

Trucks, Walkie Electric......Design of this new truck features compactness & safety for the operator. Other specifications: 3 travel speeds, easy maintenance & lightweight construction. Request Bulletin 860.
502D Raymond Corp.

Unloaders, Boxcar......Describes the Kar-Flo boxcar unloader, which utilizes oscillating motion to empty grain & other free-flowing bulk materials from railroad boxcars at rate of 4 cars per hr. Folder 2645.
502E Link-Belt Co.

Vibratory Equipment......Electro-permanent magnetic Hi-Fi vibratory equipment needs no rectifier. Operates at 3600 CPM directly off an AC line. Units are automatically self-adjusted. Request data.
R451 *Eriez Mfg. Co.

Heating & Cooling

Burners......Surface burners give you peak combustion efficiency. You can easily adjust a Surface inspirator to give correct gas-air ratios uniformly over the entire operating range. Bulletin SC-156.
L514 *Surface Combustion Corp.

Burners, Ribbon ...... Selas ribbon burners are specially designed gas-fired heating units which produce a narrow, uniform sheet or "ribbon" of flame. Employed in continuous heat processing application. Bul. SC-1004.
502F Selas Corp. of America.

Combustion Equipment.....Eclipse "Process Designed" combustion equipment fires immersion heating tanks for finishing aluminum. Request Catalog describing Eclipse's line of combustion components.
421 *Eclipse Fuel Engrg. Co.

Condensers, Surface......Ross surface condensers serve power plants everywhere. Qualified engineers can help you in the solution of condensing and heat exchange problems. Request your copy of Bulletin 8.2K1.
96 *Ross Heat Exchanger.

Heat Exchangers......B&G Exchangers feature: efficient design, special features, precision workmanship, & correct selection & handling of materials. Request B&G catalog showing application range.
327 *Bell & Gossett Co.

Heat Exchangers......Illustrated, 16 p. Design Manual provides basic information on the characteristics, design, and operation of the Pyrex modular shell and tube heat exchanger units. Bulletin No. PE-33.
502G Corning Glass Wks.

Heat Exchangers......Designers & builders of bends, coils, condensers, coolers, heat exchangers, heaters, piping, reboilers, etc., offer reference to help select your heat transfer equipment. Bulletin No. 250.
372 *Whitlock Mfg. Co.

*From advertisement, this issue

Heat Exchangers......Two new bulletins describe the distinctive features, applications & design details of the G-R twin G-Fin Section & the G-R fin-fan Exchanger. Request Bulletin Nos. 1401 & 2400.
503A Griscom-Russell Co.

Heat Exchangers......New bulletin contains data & illustrations of interest to designers & users of custom-built heat transfer equipment. Describes a number of available heat exchanger types. Request Bulletin HE.
503B Downingtown Iron Works.

Heat Exchangers......The improved design heat exchanger, Type "BD", has proved efficient under stringent conditions in the petroleum, power, chemical processing, and other industries. Bulletin Supplement 12-HS.
503C Schutte & Koerting Co.

Heat Exchangers, Impervious Graphite......Accommodates operating pressures in 150-200 psi range; simple design results in good resistance to physical shock; easy shell side cleaning. Details in Bulletin No. 537.
503D Falls Industries.

Heat Exchangers, Plate......High thermal efficiency, high pressure resistance, precision tightening, simple cleaning. To get all the facts, request the "DeLaval Heat Exchanger Bulletin" today.
79 *De Laval Separator Co.

Heat Transfer Systems.......Capacities can range from small portable units to large gas- or oil-fired units generating from 250,000 to over 10,000,000 B.T.U.'s per hour. Request names of designers & manufacturers.
386b *Monsanto Chem. Co.

Heaters, Induction......Offers new literature item listing application, features, description, operation, specifications & ordering directions for Sixty-Cycle Induction Heaters. Request your copy of Ref. No. GEA-6036.
503E General Elec. Co.

Ovens, Laboratory & Production......New, illustrated brochure describes re-designed models of laboratory & production ovens. Includes new engineering, construction & control features for "V" series ovens. Bul. 100.
503F Despatch Oven Co.

Pumping & Heating, Fuel Oil......Gives information on fuel oil pumping & heating units designed to prepare, for combustion, all grades of fuel oil including No. 6 or Bunker "C" oil & residiums. Bulletin 40.
R516 *National Airoil Burner Co.

Refrigeration Condensing Units......Offers commercial units from ½ to 10 H.P. Discusses air cooled and water cooled units, capacity control, dimensional data, gasoline driven units and truck units. Catalog 47.
503G Brunner Mfg. Co.

Steam Systems.....Sterile, Pyrogen-Free Water from Boiler Steam with Selas Steril-Aqua System. New direct method produces up to 500 gallons per hour automatically, economically. Offers descriptive literature.
336 *Selas Corp. of America.

Towers, Cooling......Special features. Superior shaft seals, heavier bearings, more conservative horsepower ratings, more rigid housing & more positive lubrication. Get your new Pritchard Cooling Tower brochure.
L447 *J. F. Pritchard & Co.

*From advertisement, this issue

Now turn to the back . . .

Simply circle the code numbers desired on the handy pre-paid postcard, and mail it to us. Replies will reach you direct from the companies manufacturing the products.

LITERATURE . . .

Traps, Cold......Offers new literature item listing application, features, description, specifications, principle of operation & ordering directions for cold traps for liquid sodium system. Ref. No. GEA-6456.
504A General Elec Co.

Traps, Steam.......Company's product line features long trap life with infrequent maintenance. Makes available on request a 44 p. Steam Trap Book with practical information designed to give you better trapping.
32-3 *Armstrong Mach. Wks.

Traps, Steam.....Give faster, more effective condensate removal. Powerful valve action, positive shut-off, high capacity & each unit service tested. For more details, request new Bulletin No. 10-55.
66 *W. H. Nicholson & Co.

Traps, Steam.....Yarway Impulse Steam Traps feature: Small size—lightweight; only one moving part; stainless steel; won't freeze up. For information request Trap Selector 24 p. Bulletin.
343 *Yarnall-Waring Co.

Traps, Steam......Machined from a solid block of stainless steel, this trap has only 3 parts . . . cap, disc, & body . . . no valve-closing mechanisms. Only moving part is a solid steel disc. Bulletin No. 257.
362 *Sarco Co.

Instruments & Controls

Amplifiers......4 p. data folder contains descriptions & schematic drawings of 4 typical applications of the new direct current amplifying instrument. Also voltage & current amplification information. Data Sheet No. 80-1.
504B Fielden Instrument Div.

Analyzers, Oxygen......A new 16 p. fully illustrated catalog explains principle, construction and features of both the paramagnetic type Magno-Therm analyzer and the electronic recorder. Request Catalog 55-829-56.
504C Hays Corp.

Analyzers & Recorders......Chart final yield and H_2-N_2 ratio before and after recycle gas enters feed stream. L&N Analyzers have been proven successful throughout the process industries. Folder ND46-91(2).
*Leeds & Northrup Co.

Computers......The Bendix G-15 is a high speed, large capacity digital computer and it is low in cost. Can be used economically in engineering, research and control functions. Request information on G-15 computers.
363 *Bendix Aviation Corp.

Control, Moisture......"Moisture Control by Vi-Speed" describes the Vi-Speed improved method for removing moisture from air, hydrogen, nitrogen and natural gas lines. New model specifications, dewpoint chart, etc.
504D Van Products Co.

Control Stations, Sodium Oxide....... Offers new literature item listing application, features, specifications, description & ordering directions for Sodium Oxide Control Station. Available on request Ref. No. GEA-6453.
504E General Elec. Co.

Control Systems......Electronik instrumentation with Electr-O-Volt relay provides continuous throttling in saturable reactor control systems. Request your copies of Catalog 1531 & Bulletin 8420.
62 *Minneapolis Honeywell.

Controls, Liquid Level......Five-Point versatility solves processing and power plant control problems. Wide selection of ranges, pressure ratings & materials. For details on 12000 Series models, see Catalog.
286-7 *Mason-Neilan.

* From advertisement, this issue

Controls, Valve......Time, labor & money can be saved by opening & closing valves with LimiTorque . . . "just press the button." There's a type & size of LimiTorque for every valve operating need. Catalog L-550.
156 *Philadelphia Gear Works.

Excitation Units......Announces new catalog on the JAco Varisource for spectrochemical analysis. Made in 3 standard models, each available with up to 5 different excitation circuits. Catalog V2-56.
505A Jarrell-Ash Co.

Fractometers, Vapor......Model P-E 154 vapor fractometer gives you Butene separation in 15 minutes. Revolutionary advance in the field of gas & volatile-liquid analysis. Request descriptive Bulletin.
112 *Perkin-Elmer Corp.

Gages......For pressure, vacuum or compound service. There are no gears or teeth to wear out. Cam wiping action keeps contact points clean & smooth. Provides complete information in Gage Catalog No. G-2.
416 *Helicoid Gage Div.

Gages, Mechanical Force......New brochure full of actual "how to do it" pictures for Model X Gage. An ingenious instrument for precision measurement of pressure, tensile or torque. Bulletin 11E.
505B W. C. Dillon & Co.

Gages, Vacuum......with 6 ranges covering pressures from 1000 mm. to 0.1 micron. Equally ideal for the laboratory & production floor. It is precisely accurate & nearly immune to abuse. For details see Bulletin G-20.
367 *National Research Corp.

Indicators, Dual Lamp......New "model 1F" miniature indicator light has two independently wired bulbs and indicates four different conditions. Used in process control systems. Details in Data Sheet 228.
505C Eldema Corp.

Indicators, Liquid Level......Offers new literature item listing application, principles of operation, features & description of Liquid Level Indicators for electrical-conducting fluids. Request Ref. No. GEA-6454.
505D General Elec. Co.

Indicators, Plugging......Offers a new literature item listing application, features, description, specifications, principle of operation & ordering directions for plugging indicators. Request Ref. No. GEA-6457.
505E General Elec. Co.

Instruments, Process Control......Illustrated, 8 p. Catalog describes electro-optical instruments for process control. Includes data on: OptiTherm Infrared Radiometers; OptiTherm Infrared Detectors; etc.
505F Barnes Engrg. Co.

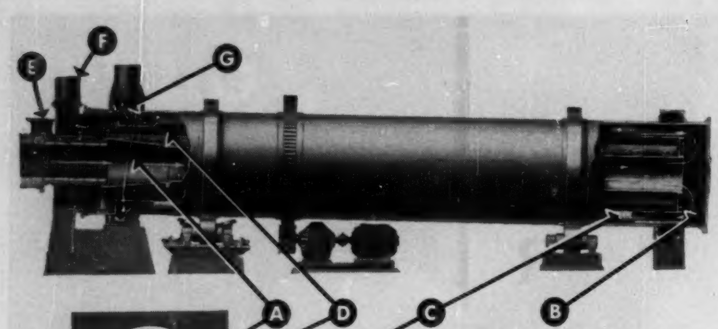
Meters, Flow, Magnetic......Offers new literature item listing application, features, description, operation & specifications of meters for flow measurements of Molten Metal. Request Ref. No. GEA-6360.
505G General Elec. Co.

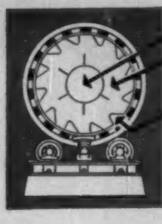
Meters, Fluid......New bulletin describes Fluidometer automatic metering system for batching light or heavy liquids. Installations of direct control, remote control, dual valve & multi-valve systems shown. Bul. FL-56.
506A Hetherington & Berner.

Meters, Liquid......Improve quality control with meter-printed batch tickets. Control pumps, valves, etc. with auto-switch meters. You can measure faster with Neptune disc-type liquid meters. Bulletin 567A.
499 *Neptune Meter Co.

Meters, Positive Displacement.......For measuring gas from 4,000 cfh to a million, you can trust the qualities of R-C Positive Displacement meters. R-C "plur-ability" pays dividends. Details in Bulletin No. M-152.
339C *Roots-Connersville Blower.

*From advertisement, this issue



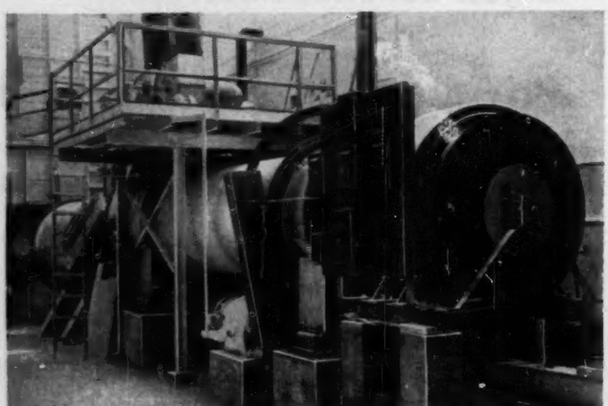


A. Central flue for hot furnace gases.
B. Header for center flue and return hot gas ducts.
C. Hot gas ducts.
D. Drying area for material.
E. Feed head.
F. Vapor discharge head.
G. Furnace gases discharge head.

Ruggles-Coles INDIRECT-FIRED DRYERS and HEATERS

- Dry without contamination from combustion gases, regardless of fuel.
- Minimize auxiliary dust collection when handling fine precipitates and filter cake.
- Heat pulverized materials for process work.
- Collect vapors at high concentration.
- Available fabricated with heat and corrosion-resistant metals.

Ruggles-Coles Indirect Heat Dryer handling 200 mesh talc.



Write for complete specifications. Ask for Bulletin AH-438-11

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LITERATURE . . .

Monochromators......The Model 220 Vacuum Ultra-Violet Scanning Monochromator is designed to produce a maximum of work results with a minimum of operator effort. Illustrated Booklet.
506B Paul M. McPherson.

Positioners, Power......Hagan units offer: High precision, low maintenance, uncomplicated design and strong construction. For full data on these "Muscles for Industry," request Specification File TP-MFI.
88 *Hagan Corp.

Positioners, Valve......The Type C Vernier Valvactor is the simplest mechanical design of any valve positioner. It offers unique flexibility, super response, extra speed & positive positioning. Request details.
301 *Foxboro Co.

Recorders......Three catalog sections discuss recording equipment—recorders, accessories & attachments, charts & writing system supplies. For further details request Catalog Sections 38-56, 80-56, 90-56.
506C Esterlin-Angus Co.

Recorders.......Offer valuable features: pre-calibrated plug-in receiver units; up to 4 pneumatic or electronic receivers—or 2 receivers & 2 integrators; etc. Products Spec. E12-5 & actual chart sample on request.
170 *Bailey Meter Co.

Recorders......New microammeter millivoltmeter recorder operates on force-balance principle, gives high-speed recording, records on 3" continuous strip chart or IBM-type card chart. Bulletin MG10.
34 *Manning, Maxwell & Moore.

Recorders, Temperature......It is easy to record temperatures and other D. C. signals on one chart with T-E's new AutoRef Cold Junction Unit. Cold-end compensation for thermocouple circuits. See Bulletin 80.
452 *Thermo Electric Co.

Regulators, Jet Pipe.......The simplest accurate long-life solution to any regulator problem. For further information on type of regulator control which best fits your operation, refer to Bulletin No. 139.
418A *Askania Regulator Co.

Regulators, Unit......Entirely self-contained for automatic control of flow, pressure, proportioning and other variables. Versatile, accurate, dependable, designed to give long efficient service. Bulletin 155.
418B *Askania Regulator Co.

Test Equipment, Environmental....... Newly published booklet, "How To Save Thousands of Dollars . . ." illustrates and describes many types of environmental test equipment. Performance and operating data.
506D Murphy & Miller.

Thermometers......Rugged . . . Accurate . . . Convenient for laboratory and equipment needs. Weston all-metal thermometers are more convenient to use, and far more economical. For the complete story, see Bulletin T-13.
377 *Weston Elecl. Instrument Corp.

Transmitters, Potentiometer.......Adaptable for the measurement of a wide variety of variables, & can be quickly modified for use with different electrical primary elements. Request Bulletin No. 98262.
46-7A *Taylor Instrument Cos.

Transmitters, Pressure......Offers new literature item listing application, features, description, operation, specifications, dimensions & ordering directions for pressure transmitters. Request Ref. No. GEA-6455.
507A General Elec. Co.

Transmitters, Temperature & Pressure......Transaire Temperature, Pressure & Differential Pressure Transmitters have created new standards in the measurement of dynamic temperatures & pressures. Bulletin 98097.
46-7B *Taylor Instrument Cos.

*From advertisement, this issue

Valve Actuators, Electro-Hydraulic...... Here is an electronic controller which is electrical all the way . . . to the final element. New reference gives complete details. Request your copy of Bulletin No. 200.
507B Askania Regulator Co.

Pipe, Fittings, Valves

Bolts, Alloy Steel......Ell bolts can be reassembled without distortion or leak development. Tightening is easy & positive . . . absolutely leak proof. For details on the "Key" to leak control, request Bulletin HE-6.
259 *Henry Vogt Machine Co.

Cocks, Sleeve-Packed......The Klinger Cock is kept tight by means of a resilient renewable packing sleeve, which is firmly compressed around the plug. For full details on Klinger Cocks, request descriptive literature.
265 *Klinger Corp. of America.

Couplers.......Kamlok quick couplers—the fastest, surest coupling known. They couple & uncouple instantly regardless of hook-up. Useful in industrial hose lines, fuel delivery & marine service. Bulletin F-10 on request.
306 *Jordan Corp.

Elbows, Long Tangent......Feature many advantages: save pipe; often eliminate short nipples and their extra welds; save time and money in lining up and clamping pipe and fitting; etc. Catalog No. 54.
385a *Midwest Piping Co.

Fittings......Describes the company's line of one-piece, abrasion-resistant, wear-back fittings. Designed primarily for hydraulic materials handling systems. Send for your copy of Data Sheet Wc.
507C Allen-Sherman-Hoff Co.

Fittings, Metal Pipe......2 p. bulletin describes impact fittings for pneumatic materials handling systems. Fittings have separate, reversible wear-back which provides high abrasion resistance. Data Sheet Wb.
507D Allen-Sherman-Hoff Co.

Fittings, Nylon......This new development is a lightweight nylon fitting which is impervious to most acids & alkalies & is guaranteed not to crack or leak under normal conditions. "Jaco—the Zytel Miracle Fitting."
507E Jaco Mfg. Co.

Fittings, Nylon Plastic....These two-piece fittings can be used with either metal or plastic tubing. Offer numerous advantages: lighter weight, lower cost & greater resistance to attack by acids. Bulletin Series 1100.
507F Thomas Associates.

Fittings, Stainless & Alloy Steel...... Engineering data & size dimensional information included in new 8 p. bulletin. Used for high temperature & corrosive applications in process industries. Bulletin S-1-55.
507G Watson-Stillman Fittings Div.

Fittings, Stainless Steel.....Speedline fittings simplify pipeline design. Details of the greater design flexibility possible with Speedline fittings . . . at lower cost . . . in new fully illustrated catalog.
388 *Horace T. Potts Co.

Hose, Flexible Metal......Three steps can help you select metal hose for best results—send exact specifications, use standard metal hose where possible, call Anaconda representative. Catalog CC-400.
167 *American Brass Co.

Hose, Flexible Metal......Engineered and manufactured to absorb the costly beating your piping system is now taking—and do it efficiently and economically. Available from stock in Bronze, Carbon Steel & Monel. Bulletin IND 4.
439 *Packless Metal Hose

* From advertisement, this issue

LITERATURE . . .

Joints, Ball......4 applications for Barco Flexible Ball Joints are: To permit movement; to accommodate expansion & contraction; to provide for alignment; to insulate against vibration & shock. Refer to Catalog 215B.
358 *Barco Mfg. Co.

Joints & Bellows......Sola-Flex bellows & expansion joints are made in all sizes & varieties. They are durable, economical, & are based on advanced engineering designs. Be sure to request the latest catalog.
332 *Solar Aircraft Co.

Joints, Expansion......New, illustrated 24 p. Expansion Joint Design Guide contains engineering application & selection data that is necessary to the proper solution of pipeline expansion problems. Catalog No. 153.
508A Flexonics Corp.

Joints, Swing......Swing joints can be furnished with gaskets for any liquid-handling service in the chemical & processing industries. Details on the 400 series steel swing joints, in new Catalog.
366A *Wheaton Brass Wks.

Nozzles, Spray ...... Company makes available on request a completely detailed Catalog which provides valuable data on Spraco Nozzle line. Includes information on full cone, flat spray & hollow cone types.
433 *Spray Engrg. Co.

Nozzles, Spray......Company provides a 48 p. industrial catalog with full data on thousands of standard and special nuzzles—for every type of spraying. Also information on related equipment. Catalog No. 24.
TL451 *Spraying Systems Co.

Nozzles, Spray......Describes company's line of nozzles for: oil burners; humidifying; air washing; desuperheating; spray drying; acid chambers; chemical processing; cooling ponds; etc. Request Catalog I.
R514 *Monarch Mfg. Wks.

Pipe & Fittings......Contamination protection of pure nickel at 1/6th cost with Lectro-Clad Nickel Plated Seamless Steel Pipe and Fittings. Request fully illustrated catalog covering technical data & applications.
413 *Bart Mfg. Corp.

Pipe & Fittings, Aluminum......New Alcoa book tells how, where, why to use Aluminum Pipe & Fittings. Gives: Process piping applications; pipeline applications; portable piping applications. Request your copy.
375 *Aluminum Co. of America.

Pipe & Fittings, Glass......Glass Pipe & fittings for full-scale production operations. Strengthened by end-tempering & feature corrosion-resistance, non-contamination, etc. Catalogs EA-1 & EA-3 offer full data.
50-1a *Corning Glass Wks.

Pipe & Fittings, Glass......New catalog describes pipe and fittings primarily designed for laboratory or pilot plant use and other special services. Sizes from ½-inch to 1-inch, internal diameter in stock for shipment.
508B Fischer & Porter.

Pipe Installation, Glass......Pipe is easy to install & low in installed cost compared with other corrosion-resistant materials. Available in 6 standard sizes from 1- to 6-inch. I.D, inclusive. Installation Manual PE-3.
50-1b *Corning Glass Wks.

Pipe, Plastic......General-purpose moderately priced rubber-plastic pipe handles most common chemicals to 170° F...except few strong acids & organic solvents. Tough, odorless, tasteless. Bulletin No. 80.
426b *American Hard Rubber Co.

Pipe, Saran Lined......Saran lined pipe, fittings and valves cut corrosion costs . . . can be cut in the field with available pipe fitter's tools. Liquid never touches metal in saran lined pipe. Request details.
333 *Saran Lined Pipe Co.

* From advertisement, this issue

Pipe & Tubing......Folder gives maximum stress values for ferrous pipe & tubing. Includes the values at various temperatures for complete range of seamless & welded carbon, alloy & stainless tubing steels. TDC-154A.
509A Babcock & Wilcox Co.

Pipe & Tubing, Steel......Furnishes information on analysis, mechanical & physical properties & creep & rupture data on various tubing alloys used in elevated temperature service. Request TDC-163A.
509B Babcock & Wilcox Co.

Piping......New 12 p. brochure tells how processing & power piping costs can be reduced substantially—in materials, design & construction. Copies of the booklet, "Piping Flexibility Analysis," are available on request.
509C M. W. Kellogg Co.

Tubes ...... Look at the advantages of Bridgeport balanced-wall duplex tubes. Balanced in wall thickness, for better safety, for longer service, in metal specification to resist corrosion. Duplex Tube Technical Bulletin.
357 *Bridgeport Brass Co.

Tubing, Flexible......Hundreds of applications in the steam and Diesel power fields are filled by Penflex flexible tubing. For complete information on product line, request copy of "Flexineering" booklet.
172 *Pa. Flexible Metallic Tubing.

Tubing, Stainless Steel......In selecting tube materials you should bear in mind (1) the difference between initial cost & installed cost (2) the degree of corrosion & oxidation protection afforded. Bulletin TB365.
391 *Babcock & Wilcox Co.

Tubing, Teflon......Offers brochure on prices & sizes for Teflon Thin-Walled & Spaghetti Tubing. Brochure gives complete information on properties, characteristics & suggested end uses. Form No. 564 on request.
509D Sparta Mfg. Co.

Valves......Circular describes new line of five bronze, solder-end valves. Valves are adaptable to all types of commercial structures & industrial applications & they embody exclusive Lunkenheimer features. Circular 603.
509E Lunkenheimer Co.

Valves......Hoke, Inc. has just published a new wall chart on Hoke valves with valuable information on valve sizing and corrosion resistance. The company makes this chart available to you upon your request.
420b *Hoke, Inc.

Valves, Automatic Drain......Offers illustrative & descriptive catalog-bulletin, "New Greenwood Automatic Drain Valve." Extremely simple to install, net weight 1 lb., 3" in length. Bulletin GV-14.
510A Vernon Tool Co.

Valves, Butterfly......New comprehensive Catalog—in loose-leaf form—includes a description of each valve, with specifications, layout drawings & dimensions of standard valves in each pressure rating. 48 p.
497 *S. Morgan Smith Co.

Valves, Control......Announces new 6 p. bulletin on company line of Speed King pilot operated control valves. Describes in detail the operation, uses, optional features, etc., of these valves. Bulletin SK356.
510B Valvair Corp.

*From advertisement, this issue

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LITERATURE . . .

Valves, Diaphragm......Describes Grinnell-Saunders diaphragm valve with straight-through flow. Includes advantages, maintenance, design, selection of bodies and bonnets, etc. Fully illustrated bulletin.
16 *Grinnell Co.

Valves, Diaphragm......From antibiotics to the toughest acids, alkalis and salts, there is a combination of Hills-McCanna body and diaphragm materials that will best suit your needs. Request Valve Catalog.
283 *Hills-McCanna Co.

Valves, Drain......Offers descriptive information on line of Strahman ram type valves...the only drain valves that cannot clog up. Made in any cast metal to meet your requirements. Request complete Catalog.
R449 *Strahman Valves.

Valves, Drain or Sampling......New Jerguson Drain or Sampling Valve is completely self-draining, withstands severe conditions, and offers foolproof operation. Request complete details on Drain Valve No. 23.
R453 *Jerguson Gage & Valve Co.

Valves, Flow......Simplicity & good design features in Powers Flowrite Valves. Accurate control results from smooth rolling diaphragm & minimum of valve stem friction. For complete details, request series 344 bulletins.
341 *Powers Regulator Co.

Valves, Gate......For pressures up to 150 lbs. & temperatures to 180° use iron body gate valves with permanently bonded hard rubber lining. In rising stem, cylinder or motor operated, or quick-opening types.
412 *Darling Valve & Mfg. Co.

Valves, Needle......The bar stock valve will contribute ease of operation, low maintenance cost and neat appearance to your equipment. Valves have an O-ring stem seal—operates at a touch. Request Bulletin.
420a *Hoke Inc.

Valves, Plug......For special services—handling products that will harden or congeal at ordinary temperatures—Wedgeplug Valves can be supplied steam-jacketed. Offers full details in Wedgeplug Catalog 55-1-W.
125 *Wedgeplug Valve Co.

Valves, Plug......If your problem is temperature, pressure or corrosion . . . Homestead Lever-Seald Plug Valves will solve it. Give extra long, leak-proof service. See Valve Reference Book No. 39-3.
395 *Homestead Valve Mfg. Co.

Valves, Porcelain......Company makes available detailed literature covering the features and advantages of porcelain valves. Bulletin includes complete description, characteristics and specifications of product line.
349 *Lapp Insulator Co.

Valves, Reducing......4 p. bulletin describes two models of Spence direct-operated water pressure reducing valves. May be used with fast-acting equipment like flushometers & snap cocks. Request your copy.
511A Spence Engineering Co.

Valves, Rotary Airlock......The Mikro Airlock is available for low or high pressure use. It is furnished with various types of rotors & vanes to meet specific requirements. See Rotary Airlock Bulletin.
374 *Metals Disintegrating Co.

Process Equipment

Agitators, Radial Propeller ...... For blending liquids, dissolving solids in liquids, mixing gases with liquids, aerating, gasifying. Operated in any type open or sealed vessel. Bulletin 58-W.
77 *Struthers Wells.

*From advertisement, this issue

Air Cleaners, Electronic......Booklet describes the Precipitron air cleaner for commercial & industrial applications. Complete with pictures, drawings & specifications. For further details, request Booklet B-1425.
511B Westinghouse Sturtevant Div.

Blenders, Spiral......New Catalog gives exact specifications in light, medium and heavy duty blenders offered, plus information on special order design and service. Points out money-saving & time-saving improvements.
423 *American Welded Tank & Machy.

Collectors, Multi-Wash......For the efficient removal of air-borne contamination (dust, fumes, vapors, acid gases and odors) and recovery of product thru multiple washing action. Details in Bulletin Nos. 351 & 610.
L449 *Claude B. Schneible Co.

Crushers, Cone......For the reduction crushing of ores, rock products & industrial minerals. The operation & design features of these Symons Cone Crushers are described in complete detail in Bulletin 247.
511C Nordberg Mfg. Co

Demisters......Yorkmesh Demisters improve process vessel performance by effecting clean separation of liquid from vapor. Request a complete list of the many case histories available and Bulletin No. 17.
392 *Otto H. York Co.

Discs, Tank Car......New Tank Car Disc by BS&B meets the demand for a serviceable disc that will not corrode or fatigue while the car is in transit. Model TC prevents unnecessary product loss. Request more details.
438 *Black, Sivalls & Bryson.

Dissolvers......for processors of liquid-liquid. gas-liquid & solid-liquid products, including . . . Chemicals, Paints & Inks, Plastics, Pharmaceuticals, Foods & Beverages. Many models to choose from. Request details.
311 *Morehouse-Cowles, Inc.

Dragscrapers......New catalog gives full details and specifications on Dragscrapers Machines. Covers standard installations, Rapid Shifting Dragscrapers. track cable machines and tower excavators. Catalog A.
511D Sauerman Bros.

Dryers......Ruggles-Coles indirect-fired dryers and heaters; dry without contamination from combustion gases, regardless of fuel; collect vapors at high concentration; etc. Data in Bulletin No. AH-438-11.
506 *Hardinge Co.

Dryers, Rotary......The Davenport rotary hot air dryer is of stainless steel construction. Dryer is installed in one of the large processing plants, drying wheat gluten. For complete details, request Catalog A.
B520 *Davenport Mach. & Foundry.

Drying Systems, Flash......Systems offer means for handling materials in which drying is combined with pulverizing, or with mild disintegration, or followed by cooling & conveying product to storage. Catalog 82.
406 *Raymond Div.

Duct Systems......Boltaron 6200 Type I PVC has outstanding resistance to corrosive gases & liquids, alkalies & acids. Boltaron 7200 PVC is available when conditions permit the use of a Type II PVC. Bulletin 4B.
458 *H. N. Hartwell & Son.

Dust Collectors......Maximum filtering efficiency, bag cleaned uniformly and automatically, overcleaning eliminated to prolong bag life, easy to assemble in less space. For further details, request Aeroturn Booklet.
325 *Koppers Co.

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LITERATURE . . .

Dust Collectors......In almost every type of industry . . . users have found high efficiency, simplicity & economy of Dustube collectors a difficult combination to equal for top performance. Bulletin No. 372.
271 *Wheelabrator Corp.

Dust Collectors......New booklet, "The Collection and Recovery of Industrial Dusts" is available upon request. It describes the "SF" electric precipitators and how they meet all 5 basic requirements for top efficiency.
334 *Buell Engrg. Co.

Dust Control......Pangborn engineers help solve your dust problems—line of wet or dry dust collectors can save time, trouble & money. See how varied industries are benefited in "Out of the Realm of Dust."
425 *Pangborn Corp.

Ejectors......The Penberthy 63A Ejector eliminates boiling or handling of slurry by operator. Penberthy products are simplifying operations and saving time and money. Request complete facts.
396 *Penberthy Infector Co.

Ejectors......Elliott's 5-stage ejectors are applied when absolute pressures ranging from .012 in (0.3mm) to about .003 in. (0.075mm) mercury are required. For details on complete line, request Bulletins.
436 *Elliott Co.

Ejectors, Steam-Jet......Presents a 60 p. "Steam-Jet Ejector Application Hand-Book" for selection of single and two-stage stock ejectors for general vacuum service. Photos, tables, graphs, etc. Bulletin W-205-E21.
387 *Worthington Corp.

Filters......All types of continuous rotary vacuum filters . . . string horizontal, scraper, precoat, etc. . . . are custom designed & manufactured by FEinc. Company makes available Bulletins.
331 *Filtration Engrs.

Filters......New built-to-order vertical filters solve complex problems & are easily adapted for special uses. For details on flow systems, special equipment, filter & leaf construction, request Bulletin No. 111.
445 *Industrial Filter & Pump.

Filters, Air......Mechanical Filter for ventilating & air conditioning service. Airmat PL-24 gives highest efficiency plus low initial cost. Requires no oil, no water for washing. Complete details in Bulletin 230.
92 *American Air Filter Co.

Filters, Horizontal Plate......The new Niagara "Batch Miser" Horizontal Plate Filter leaves no heel at the end of the cycle. Features no tie rods and less down-time. Request Bulletin with complete data.
488 *Niagara Filter Div.

Generators, Inert Gas ...... Assures a safe, dependable supply of chemically clean inerts. Deliver inerts at a special analysis . . . without fluctuations. For facts and technical data, request Bulletin 1-10.
321 *C. M. Kemp Mfg. Co.

Homogenizers, Laboratory......Fully illustrated booklet describes the Gaulin Laboratory Homogenizer . . . specially designed for research, pilot plant or limited production operations. Request your copy of Folder No. LH-55.
513A Manton-Gaulin Mfg. Co.

Kilns, Rotary......Efficient thermo-processing of products. Used in the production of lime, bauxite, cement, sodium silicate, alumina, etc. Complete data on design features offered in illustrated Bulletin 1115.
158 *Traylor Engrg. & Mfg. Co.

Lubrication Systems......The Alemite Oil-Mist System offers: Continuous and fully automatic lubrication, elimination of guesswork, reduction of bearing temperatures. New Oil-Mist catalog.
13 *Stewart-Warner.

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Mills, Tube & Rod......Continuous feed and discharge, wet or dry, in open or closed circuit, produces the utmost in grinding performance and economy. Each mill is engineered for its job. Request details.
435 *Patterson Foundry & Mach. Co.

Mixers......Company makes available Confidential Mixing Data Sheet. Helpful checklist enables you to develop a complete technical description of agitation required for your process, quickly & easily. No. B-107.
257a *Mixing Equipment Co.

Mixers......The Abbe Dispersall Mixer gives you power & speed, plus the tremendous advantage of easy cleaning, which readily allows shifting from one color or formulation to another. See Catalog 78.
492 *Abbe Engrg. Co.

Mixers, Centrifugal......"High Speed Mixing with Entoleter Centrifugal Machines." Better quality, easily cleaned, compact size of equipment, more efficient processing . . . lower cost texture improved . . . etc.
513B Entoleter Div.

Mixers, Portable......Use in industry reduces costs, saves time, labor and secures better and more refined products. Catalog includes data on construction, dimensions, specifications, etc. 28 p. No. B-108.
257d *Mixing Equipment Co.

Mixers, Side Entering......Furnishes detailed information on features, typical applications, mechanical design, maintenance, shaft seals, methods of installation, etc., in completely illustrated Catalog B-104.
257e *Mixing Equipment Co.

Mixers, Top Entering......Illustrated and detailed 32 p. Catalog includes advantages, typical installations, mechanical description, construction information, dimensions and selection tables, etc. Catalog No. B-102.
257f *Mixing Equipment Co.

Mixers, Top Entering......Makes available pertinent information on top-entering mixers (propeller type) . . . for closed tanks, pressure & vacuum . . . for open & loose-covered tanks. Data in Catalog No. B-103.
257G *Mixing Equipment Co.

Process Equipment......New 8 p. bulletin describes spiral ribbon mixers, double-arm mixers, planetary-action vertical mixers, laboratory mixers, sifters, storage bins, weigh hoppers & screw conveyors. Bulletin 55782.
513C Read Standard Corp.

Process Equipment......12 p. Corrosion Guide made available to users of corrosion resisting processing equipment as a handy reference chart. For help in selecting corrosion resisting metals —"Misco Corrosion Guide."
514A Misco Fabricators.

Process Equipment, Chemical......Engineers are available to assist you in design and large, modern facilities can meet your most difficult machining and fabrication requirements. Bulletin P-55 on request.
368 *Treadwell Construction Co.

Process Equipment, Fabricated......For your most efficient means to fast, economical production, for individualized equipment designed & constructed to fit your needs, request a copy of Koven's Bulletin 550.
335 *L. O. Kovên & Bro.

Processing Equipment......Catalog describes Jeffrey material-handling and processing equipment. Equipment for moving materials by conveyor belts, spiral conveyors, bucket elevators & scraper conveyors. Catalog 860.
346 *Jeffrey Mfg. Co.

Processing Equipment......Describes corrosion-resistant processing equipment . . . precision built to your specific requirements to give long years of peak performance with low maintenance. Technical Bulletins.
415 *Lee Metal Products Co.

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LITERATURE . . .

Reactors......Plant Size Reactors with Lab-Equipment Precision combine the most advanced design engineering in the high pressure field with the finest materials available. Bulletin 356.
82 *Autoclave Engineers.

Screens, Gyratory......New in design, performance & economy. Top efficiency in screening . . . maximum capacity . . . profit insuring quality control . . . simplified maintenance, etc. For details, see Bulletin 07B8446.
305 *Allis-Chalmers.

Screens, Vibrating......For economical separation of light to medium weight materials—choose "UP" vibrating screens. In open, semi-enclosed, or totally-enclosed types. Complete details contained in Book 2377.
370a *Link-Belt Co.

Screens, Vibrating......For high-capacity screening of a broad range of materials—"CA" vibrating screens are your answer. In complete range of sizes to suit all plant capacity requirements. New Book 2554.
370b *Link-Belt Co.

Sieves, Molecular......Dry your gases—air, hydrogen, chemical streams—more thoroughly than any other commercial absorbent. For details, request data sheets on "Drying of Gases" now available.
295 *Linde Air Products Co.

Submerged Combustion Units......New 8 p. fully illustrated Bulletin describes line of Submerged Combustion Equipment. Covers versatility of this unique process tool as applied to a variety of process problems.
514B Ozark-Mahoning Co.

Vessels, Pressure......Developed by specialists producing pressure vessels, vacuum tanks, towers, reactors, weldments and sub-assemblies. Request this easy-to-read, illustrated booklet, "Facilities and Products."
360 *Newport News Shipbuilding.

Washers, Sub-Surface......Highly informative paper discusses the development of the "Sub-Surface Washer" . . . used in Demineralizers, Zeolite Softeners and Filters. Request copy of illustrated Technical Reprint T-139.
514C Graver Water Conditioning.

Wire Cloth......80 p. catalog describes company's facilities for fabricating wire cloth parts. Includes wire cloth parts for screening, filtering and special uses. Also provides helpful metallurgical information.
442 *Cambridge Wire Cloth Co.

Wire Cloth & Screen......In order to improve your filtering, straining, sizing operations, specify Ludlow-Saylor wire cloth & screen. Give better resistance to heat & pressures. Condensed Screen Reference Catalog.
450 *Ludlow-Saylor Wire Cloth Co.

Pumps, Blowers, Compressors

Blowers......Wherever bad air slows down production . . . in shipholds, tanks, drums, boilers or other places where men need fresh air . . . a Coppus blower becomes a safety device & a production tool. Request details.
101 *Coppus Engrg. Corp.

Blowers......Precision manufactured to move more gas or air with less wear than other blowers of equal size or weight . . . and with less maintenance and power costs. Describes line in detailed Bulletin B-154.
505 *Read Standard Corp.

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LITERATURE . . .

Blowers & Exhausters, Centrifugal...... Put air to work more effectively; take delays out of industrial processing and improve quality. For complete details, request Bulletins 120-B-14, AF-154 and RB-154.
339a *Roots-Connersville Blower.

Compressors......High pressure barrel-type compressor features: Simple to maintain—only 1 head bolted on; shaft sealing; rugged rotor—for years of high speed operation; extra strong. Request details of this design.
399 *Allis-Chalmers.

Compressors......For a full description of the vital role played by Ingersoll-Rand compressors in synthetic ammonia production, refer to Form 3223. Process plants of all types use these compressors, as shown in Form 3132.
54-5 *Ingersoll-Rand.

Compressors......RX Compressors are engineered to keep on the go. For complete details on RX models from 89 to 1292 cfm, for pressures from 15 to 150 psi, the company makes Bulletin HAC-40 available.
86 *Gardner-Denver Co.

Compressors, Air......Offers single and two stage air compressors from ½ to 20 H.P. Gives details on various models, accessories, engineering data and controls. Write for data sheet, factual booklet & Catalog 36.
515A Brunner Mfg. Co.

Compressors, Axial Flow......Carrier Axial Flow Compressors fill industry's need for a machine of large volume flow capable of operating on any gas mixture. For complete data, request descriptive Folder.
342 *Carrier Corp.

Compressors, Oil Free......Joy WGO-9 Compressor features vertical design, long-rod construction, sectionalized carbon rings, light-weight pistons & direct air passages. For details, request Bulletin 57-11.
8 *Joy Mfg. Co.

Fans......The Bifurcator is a direct-driven fan in a divided housing. Fumes bypass the motor which always stays clean, cool & accessible. Installs like a section of duct-work—at any angle. Catalog DB-37-55.
261 *Debothezat Fans Div.

Fans, Centrifugal......Offers high efficiency, low noise level industrial fans. Particularly recommended for handling hot air and gases up to 600° F. Bulletin C-102 makes correct selection quick and easy.
515B Chicago Blower Corp.

Pumps......Practical Guide to Pump Selection—illustrations & descriptions with capacities & adaptability of facts to help avoid costly misapplication. For more complete details, request Bulletin No. S-146.
L419 *Taber Pump Co.

Pumps......If you have a problem where metering, blending or other accurate pumping of liquids is concerned, let Viking help solve it. Use Viking Pumps for accurate pumping. Request information & Bulletin 56Sc.
BL451 *Viking Pump Co.

Pumps, Acid......On most difficult pumping jobs . . . dependable highly efficient pumps deliver continuous, trouble-free performance on round-the-clock schedules wherever they are installed. Full details.
153 *A. R. Wilfley & Sons

Pumps, Acid ...... Mighty midget for pumping acids. Jabsco neoprene-impeller pump made of Ace hard rubber outlasts, out-pumps anything in its pressure, size and price class. Full details in Bulletin No. 97A.
426a *American Hard Rubber Co.

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Pumps, Acid . . . . . . 80-gpm. centrifugal pump with hard rubber casing and impeller, Hastelloy C shaft. Handles nearly all corrosives. Mechanically simple, trouble-free. For information, request Bulletin CE-55.
427b *American Hard Rubber Co.

Pumps, Acid & Chemical......Pumps to handle every acid or chemical fluid used in industry. Offers help with particularly difficult chemical pumping problems. For pertinent details, request Bulletin 203-7.
408 *Lawrence Pumps.

Pumps, Centrifugal......Illustrated reference describes line of SSV centrifugal pumps. Includes details of construction of the various sizes available, operating advantages for users, etc. Bulletin No. 107.
516A Frederick Iron & Steel.

Pumps, Centrifugal . . . . . . The Eastern D-11 is the smallest, close-coupled, single-stage centrifugal pump available with an induction type motor. Complete specifications on all Eastern centrifugal pumps in Bulletin 120-B.
410 *Eastern Industries.

Pumps, Centrifugal......The Series 10 standard centrifugal pumps are built from the same parts . . . one shaft fits all pumps. For more complete information, request a copy of Circular No. 184B.
443 *Dean Bros. Pumps

Pumps, Close-Coupled......Feature the "Q" Factor . . . the built-in quality which provides trouble-free satisfaction and long life. Offers complete description of Class CCL close-coupled pumps in Bulletin 975.
441a *Buffalo Pumps.

Pumps, Condensate......New Sarco type S Condensate Pumps are close-coupled, bronze-fitted pumps. Easy to convert from single to duplex, no sub-base required, easy to take apart for inspection. Bulletin No. 1460.
516B Sarco Co.

Pumps, Condensate Return......Features bronze construction, non-clogging open impellor, stainless steel shaft. Pump affords quiet, dependable operation & has long life with little maintenance. Request details.
516C Walter H. Eagan Co.

Pumps, Direct Flow......Data Sheet illustrates & describes the Aldrich 6" Stroke Direct Flow Pump Series. Includes Triplex, Quintuplex, Septuplex & Nonduplex Pumps, ranging in power from 300 to 900 hp. Data Sheet 67A.
414 *Aldrich Pump Co.

Pumps, Double Suction . . . . . . Hydraulically balanced, highly efficient and durable. In sizes to deliver from 10 to 14,000 gpm for circulating, air conditioning, other plant services. Details in Bulletin No. 955-Q.
441b *Buffalo Pumps.

Pumps, Electromagnetic......Offers new literature item listing application, features, description & operation of A-C Electromagnetic Pumps for liquid metals & low-resistance conducting fluids. Ref. No. GEA-6395.
516D General Elec. Co.

Pumps, Electromagnetic......For high-temperature liquid metal. New literature item discusses different types and models offered. Request your copy of this informative bulletin—Ref. No. GER-1032.
517A General Elec. Co.

Pumps, Gas......Positive control of volume and pressure, with the simple rotary impeller principle. Details in Bulletin 31-B-17 for small sizes & Bulletin 32-33-B-13 for larger units.
330b *Roots-Connersville Blower.

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LITERATURE . . .

Pumps, General Purpose......Designed for a broad range of clean liquid applications, these Roper Series 3600 Pumps are recognized for highly dependable performance, low maintenance characteristics. Request Catalog.
454 *Geo. D. Roper Corp.

Pumps, Hand......New piston-type, positive-displacement, self-priming hand pump now in production delivers 20 gpm at lower "cost-per-gallon" than rotary vane-type hand pumps rated at 10 gpm. Bulletin 3011.
517B Bowser, Inc.

Pumps, High Pressure......Completely illustrated reference describes line of Gaulin High Pressure Horizontal Triplex Pumps. Includes data on construction, operation, features specifications, etc. Bulletin P-55.
328 Manton-Gaulin Mfg. Co.

Pumps, Non-Clog......8 p. illustrated booklet covers vertical, horizontal and close-coupled types. Used to handle liquid components of industrial processes, industrial waste. Write for Bulletin 121-A.
517C Aurora Pump Div.

Pumps, Paper Stock......For handling high consistency liquids—save money and trouble with non-clogging paper stock pumps. Available in alloys or rubber-lined for corrosive and abrasive liquids. Bulletin No. 953.
441d *Buffalo Pumps.

Pumps, Process . . . . . . DeLaval CPO-process pumps handle numerous liquids; salt brine; sea water; caustic solution; soap solutions; etc. Capacities to 2000 gpm—heads to 200 ft. Details in Bulletin No. 1125-B.
161 *De Laval Steam Turbine Co.

Pumps, Proportioning . . . . . . Microflex Chemical Proportioning Pump offers: simplex & duplex styles; various piston-cylinder assemblies can be used interchangeably; self-aligning pistons. See Bulletin 4065-2.
T526 *American Instrument Co.

Pumps, Slurry......Complete details of the Manzel SP-90 Slurry Pump. This new pump prevents setting; pumps slurries at rates varying from over 15 gals. maximum to 2¼ gals. minimum per hour.
517D Manzel Div.

Pumps, Sump......Three advantages are featured in the "Buffalo" sump pump; easy installation; always in prime (since there is no suction lift); & simplified maintenance. For details, request Bulletin No. 963-F.
441c *Buffalo Pumps.

Pumps, Vacuum......Important operating factors, which add up to R-C "plur-ability", account for rapidly increasing use of positive displacement vacuum pumps for industrial processing. Bulletin 50-B-13.
339d *Roots-Connersville Blower.

Services, Processes, Misc.

Acidizing Service.......New literature item contains technical information on Dowell Acidizing Service. Offers: proved, fast service; experienced engineers; specialized treating equipment.
518A Dowell, Inc.

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Air, Water & Industry......"Air, Water & Industry—Some Compressed Air Problems & How to Solve Them" describes the important story of why there is moisture in air lines, how it got there & its destructive action.
518B Van Products Co.

Anode, Magnesium......Describes details of size, weight and attachment fittings for magnesium anodes used to protect ballast tanks, ship hulls and piers against sea water galvanic corrosion. Bulletin 160.
518C Federated Metals Div.

Atomic Terms......After a recent talk by Eger V. Murphree on "The Atom in Peace," it was suggested that the company publish a glossary on atomic energy. Illustrated, 22 p. booklet defines 101 frequently used terms.
518D Esso Research & Engrg.

Autopositive Paper......Positive photographic intermediates without a negative step. New booklet describing Kodagraph Reproduction Materials gives valuable tips on getting better prints.
95 *Eastman Kodak.

Design & Engineering, Ammonia Plants......Specialized know-how embraces all phases of process and equipment design, fabrication and erection. For complete information the company makes available Bulletin 0-54-1.
135 *Foster Wheeler.

Engineering Services......Help protect your equipment investment—application engineering, analytical engineering, product development, field-service engineering, maintenance service, etc. Bulls. GED-2244, GED-1966 B.
28-9 *General Elec. Co.

Fire Extinguishers......Efficient, dependable & superior in design, new expanded line of Kidde extinguishers now make it easier for you to choose the right extinguisher for every fire hazard. P-8 Catalog.
515 *Walter Kidde & Co.

Fire Protection......"Engineered Special Hazard Fire Protection" covers methods of fire detection, fire prevention, fire control and fire extinguishment in the field of Special Hazard fire protection. Catalog 73.
518E "Automatic" Sprinkler.

Grating & Stair Treads......Blaw-Knox electroforged steel grating makes every step a safe step indoors or outdoors. Makes available new reference & quotations. For more complete information request Bulletin 2486.
493 *Blaw-Knox Co.

Industrial Location Services......"Industrial Location Services" is a new expert, factual and confidential bulletin. Make use of these services offered by the New York State Department of Commerce.
518F N. Y. State Dept. of Comm.

Laboratory Equipment ...... Investigate Sturtevant equipment for your laboratories. They will help you cut sampling cost—improve product quality—increase sales. For complete data, request illustrated Bulletin.
165 *Sturtevant Mill Co.

Patent Abstract Service.....Service keeps users continuously informed on all patents issued in any designated field. It is prompt, complete and photographically accurate. Request further information.
518G Picturesort Co.

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Quick facts about the services and equipment Pfaudler offers to help you reduce corrosion and processing cost.

Now you can outsert leaflets on most packages *without hand labor!*

Put your product story where it will be read—on a leaflet fastened to the outside of your package. You can do this, without slowing down your production line or using costly hand labor, by using Pfaudler's new fast-action Outsert Applicator, Model OA-3MC.

Up to 220 containers per minute

The Pfaudler Outsert Applicator attaches your message to all cylindrical containers of plastic, glass, paper, or metal—2⅝ to 7¼ inches in length, 1¼ to 6½ inches outside diameter. (Special designs for containers outside these limits.)

Fits right into your production line

The unit fits readily into most production line setups, *requires only four square feet of floor space!* There it operates automatically and continuously, gripping free-rolling containers from your labeling machine and forwarding them, with leaflet accurately attached, to the casing machine, ready to pack and ship.

Low maintenance cost

Advanced design and careful selection of materials give you a durable machine, capable of long continuous runs. And there are no delicate mechanisms to fail.

If you're interested in the advantages of outserts for your product, simply forward a sample labeled container with outsert affixed correctly. Pfaudler engineers will analyze your requirements and send you full information. Or, if you prefer, write for Bulletin 933.

Pfaudler Outsert Applicator attaches message to your package automatically (insert).

GET 2-WEEK DELIVERY on these flexible standard heat exchangers

Interchangeable parts are essential to the cornerstones of industrial progress. But in the chemical processing field, standardization is hard to achieve because of the great variety of requirements. Traditionally each system has had to be specially engineered.

Today it is unnecessary, in many cases, to delay your operation by waiting months for "made-to-order" heat exchangers. With the flexibility provided in Pfaudler's standard line of equipment, you can solve many process problems in two weeks—without resorting to special complicated designs.

Any one of the five sizes of Pfaudler stainless steel heat exchangers listed below can be speeded on its way to your plant.

Pfaudler's new stocking program, plus standard design, make this "off-the-shelf" delivery possible. These units are ready for almost immediate shipment and are all fixed-tube sheet design. Shell and baffles are made of carbon steel; tubes, tube sheets and bonnets are stainless steel.

These stock units may be used in vertical, horizontal or inclined positions, as specified on your order.

General specifications:

Design Pressure: 150 psi shell side; 75 psi tube side.

Design Temperature: 350° F.

Shell and Baffles: Carbon steel.

Tubes: Stainless steel, Type 316, ¾" O.D. 18 gauge, welded.

Code: Built to ASME Code U-69, but not stamped unless specified.

Diaphragm: None.

Support Lugs, Ears or Saddles: Shipped unattached, or, attached if desired location furnished.

Tube Sheets and Bonnets: Stainless steel, Type 316.

Stockpiled sizes

56 sq. ft. size—8" nominal shell diameter; 72" tube length; baffles on 4" centers.
104 sq. ft. size—10" nominal shell diameter; 96" tube length; baffles on 5" centers.
148 sq. ft. size—10" nominal shell diameter; 120" tube length; baffles on 5" centers.
216 sq. ft. size—12" nominal shell diameter; 120" tube length; baffles of 6" centers.
316 sq. ft. size—14" nominal shell diameter; 144" tube length; baffles on 7" centers.

If none of these exactly fit your needs, a wide variety of other sizes are also available for fast delivery. We can help you with unusual jobs, too. Please ask us about them.

Pfaudler will build heat exchangers to meet your special requirements in many different alloys including Nickel, Inconel, Monel, Hastelloy, Titanium and Karbate. Although Pfaudler standards are based on ¾" tubes, we can give you designs for any required tube size, and any temperature or pressure.

Engineers in the Pfaudler heat exchanger design department are at your service to work out the answers with you. Why not get in touch with them when you have a special heat exchanger problem? And write for your free copy of Manual Number 837 titled, "Pfaudler Heat Exchangers and Condensers." This manual contains valuable performance and thermal design data as well as a complete description of Pfaudler heat exchangers and condensers.

Pfaudler

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